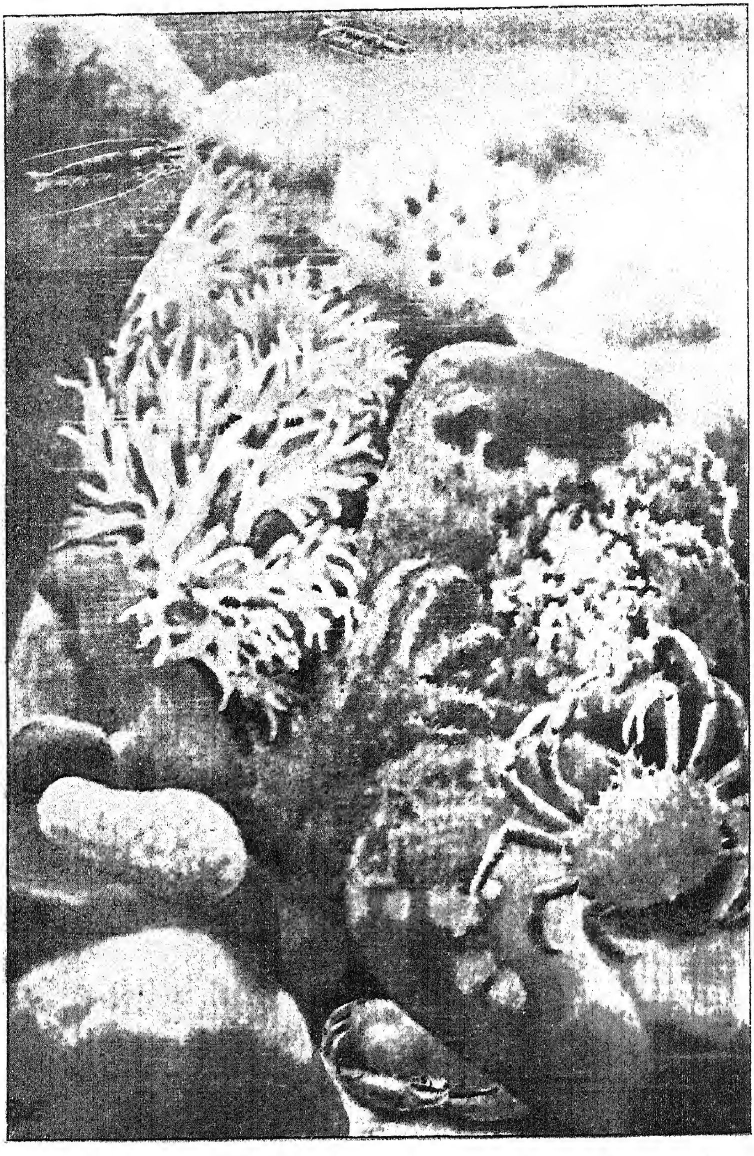
GENERAL ZOOLOGY



ANIMALS FOUND LIVING TOGETHER IN SHALLOW INLETS FROM THE SEA, LONG ISLAND SOUND

A TEXTBOOK IN GENERAL ZOOLOGY

BY

HENRY R. LINVILLE, PH. D.
FORMERLY HEAD OF THE DEPARTMENT OF BIOLOGY, JAMAICA HIGH SCHOOL, NEW YORK CITY

HENRY A. KELLY, PD. D.
DIRECTOR OF THE DEPARTMENT OF BIOLOGY AND NATURE STUDY ETHICAL CULTURE SCHOOL, FIELDSTON, NEW YORK CITY

AND

HARLEY J. VAN CLEAVE, PH. D.
ASSOCIATE PROFESSOR OF ZOOLOGY, UNIVERSITY OF ILLINOIS, URBANA, ILLINOIS

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PREFACE

This revision of Linville and Kelly's *Textbook in General Zoology* is issued under the joint authorship of Henry R. Linville, Henry A. Kelly, and Harley J. Van Cleave. The work of revising the material of the original book and the selecting and organizing of new material has been carried out by the junior author, with the coöperation and approval of the senior authors. It has been the policy throughout the revision to retain those distinctive features of method of presentation and organization which have received such general commendation and approval from teachers of biology throughout the country who are familiar with the earlier edition.

The contents of this book have been selected and arranged as the basis for a full year's course in zoology for students beginning the subject. In the revision of the original edition an attempt has been made to give a distinct biological orientation of the subject. The possibility of utilizing the text for the animal portion of a biological course has been kept constantly before the authors. In a course covering but a single semester or term, or in a biological course extending through the year, wide latitude of choice is offered the teacher.

The treatment of the phyla is in a descending order from the Arthropoda to the Protozoa, and in ascending order from the fishes to man. After many years of experience with classes of beginning students we believe that an order of this nature is likely to yield the best results. We do not deny that good results may be obtained by following what

is sometimes called the "order of evolution," beginning with the Protozoa. Although the chapters are interdependent, and biological principles are developed in large measure in the consideration of groups where they find most ready application, yet there is sufficient unity in the individual chapters to make it possible for the teacher to diverge from the sequence which we have employed.

Whatever the order followed, it is evident that recitations on the chapters in the textbook should be held only after the student has made his study in the laboratory. The textbook in science has its greatest usefulness in connecting, extending, and illuminating the work of the laboratory. Laboratory work and field observations bring the student in touch with actual things, and if the studies are properly conducted they will aid in developing the power of independent judgment. The untrained student cannot build up a conception of the science of zoology from the more or less isolated data of the laboratory and field; in this fact lies the justification of a textbook in zoology.

The inductive method of presentation, in necessarily modified form, has been followed in the earlier chapters of the book, as being the natural mode of approach to a new subject based upon laboratory work. After the study of the grasshopper, for example, another animal which has easily recognizable relationship to this form is considered. Not until the selected representatives of the Orthoptera have been described are the characters of the order mentioned. By that time the student's mind is ready for the definition of Orthoptera. The conceptions of the larger groups of invertebrate phyla and classes are developed in the same manner.

Against the possibility that direct, continuous, page sequence may be followed in a course covering only a part of the text, some of the fundamental biological material has been introduced relatively early. This explains the position

of the chapters on Some of the Life Processes (Chapter XII), on Living Matter: Protoplasm and the Cell (Chapter XIII), and on Heredity and Evolution (Chapter XVII). For a course planned to occupy less than a full year the authors recommend the omission in their entirety or in part of the chapters on The Dragon Flies (Odonata) and the May Flies (Ephemerida) (Chapter III), The Spiders and Allies: Arachnida (Chapter XIV), Allies of the Acephala: Mollusca (Chapter XIX), Allies of the Earthworms: Annelida (Chapter XXII), and The Bath Sponge and Some Allies: Porifera (Chapter XXVI). By deleting some of these chapters from the invertebrate section, the teacher may gain time for the consideration of some of the vertebrates.

Before entering upon the work of the current revision the authors secured the coöperation of representative teachers who have been using the textbook. More than a hundred biology teachers responded with personal letters and interviews concerning the details of the proposed revision. This list of our colleagues, who in innumerable ways have aided in the course of the preparation of the revision, is too long for detailed acknowledgment here. The detailed criticisms and suggestions offered by Miss Helen Loomis of the Bowen High School, Chicago, Illinois, and by Dr. W. H. D. Meier of the State Normal School, Framingham, Massachusetts, have been of great value in directing the course of the revision. Dr. T. H. Frison of the Illinois State Natural History Survey has very generously aided in numerous details, especially in the verification of entomological terms. Bernice F. Van Cleave, by constant collaboration in selecting and in rewriting material, has been in great measure responsible for whatever merit the new material may possess. As an experienced biology teacher in secondary schools her aid in maintaining proper perspective and point of view has been inestimable.

Although in the current revision there have been numerous changes in and additions to the illustrations, the drawings which have given such distinction to the original edition have been for the most part retained. These were the work of Mr. S. F. Denton, Mr. L. H. Joutel, and Mr. E. N. Fischer. In numerous instances the key letters or numerals standing at the ends of leader-lines have been replaced by full names, thus obviating the necessity of referring to a legend to secure the names. For the many courtesies which have made possible the use of drawings and photographs, acknowledgment is offered with the individual figures.

The extensive list of zoologists and specialists who aided in the course of the preparation of the original edition will be found in the detailed acknowledgment in the Preface of that edition.

It is our hope that the quotations which introduce the chapters will serve to suggest to the imagination of young students the poetic side of animal life and of nature generally. For some of the most fitting quotations we are indebted to personal friends.

H. R. L.
H. A. K.
H. J. Van C.

CONTENTS

GENERAL ZOOLOGY

CHAPTER I

THE COMMON RED-LEGGED GRASSHOPPER

Though I watch their rustling flight,
I can never guess aright
Where their lodging-places are;
'Mid some daisy's golden star,
Or beneath a roofing leaf,
Or in fringes of a sheaf,
Tenanted as soon as bound.

EDITH M. THOMAS

Distribution. Grasshoppers, or locusts, are found almost everywhere in the United States, — usually in fields, meadows, and along roadsides. There are many different kinds of grasshoppers, but the species which heads this chapter is one of the most widely distributed. It is known to naturalists as *Melan'oplus* [1] *fe'mur-ru'brum.* Its habitat (the locality where it is naturally found) comprises grassy areas in almost every state except on the high Western plains, where its place is taken by a species much resembling it, — the Rocky Mountain grasshopper, or locust (*Melanoplus spre'tus*). The lesser grasshopper (*Melanoplus atla'nis*), somewhat smaller and darker in color, is also found in nearly every part of the country. These and several other grasshoppers are about three centimeters (a little over an inch) in length, and resemble each other so closely that the following description will apply nearly as well to one as to another.

[1] The first time a scientific name is used, an accent mark is placed after the accented syllable as an aid in pronunciation.

Plan of External Structure. The entire body is covered with a hard, horny substance called *chitin*. This gives protection to the internal organs. The body is divided into three clearly marked regions: the *head*, the *thorax*, and the *abdomen* (Fig. 2). Each region is further subdivided into a series of rings called *somites*, which give flexibility to the body in spite of the hard chitinous covering. These rings are most clearly observed in the abdomen, which is made up of ten easily counted somites. The three somites of the thorax are less clearly distinguishable because they have become slightly modified and shoved together. Though the head seems to be but a single structure without division into somites, it is fairly certain that six somites have been so completely combined and fused to form the head that divisions are no longer present. The external plan upon which the grasshopper is built is thus seen to be a series of somites, of which the anterior (front) somites bear jointed *appendages* modified for various uses.

The Head. The head of the grasshopper serves in taking food and making the animal aware of its surroundings. These functions are performed chiefly by *appendages*, or paired outgrowths from the head. Certain of these appendages are purely sensory; others aid in securing and devouring food. The most conspicuous sensory appendages are the pair of slender, jointed *antennæ*, or feelers. In the grasshopper these are organs of touch and smell. Just behind the antennæ, on the sides of the head, is the pair of large *compound eyes*. Each compound eye is covered with a transparent layer of chitin which is divided into a large number of six-sided divisions, each of which is called a *facet*. Such an eye is said to be compound because each facet has beneath it the necessary structures for sight. Since the surface of a compound eye is convex, each facet points in a different direction. It seems probable that each

unit of the eye does not make a complete image, but the combined effect of all the units taken together produces a *mosaic* pattern of whatever stands in range of the lenses. In addition to the compound eyes, there are three *ocelli* (Fig. 2), or simple eyes, arranged, one almost in the exact center of the front of the head, and one directly above the base of each antenna. Notwithstanding these two kinds of eyes, it is doubtful whether the grasshopper is able to perceive well the outlines of objects or to distinguish much except light and movement. The ocelli probably do not perceive objects at a greater distance than a few inches, nor the compound eyes at a greater distance than a few feet.

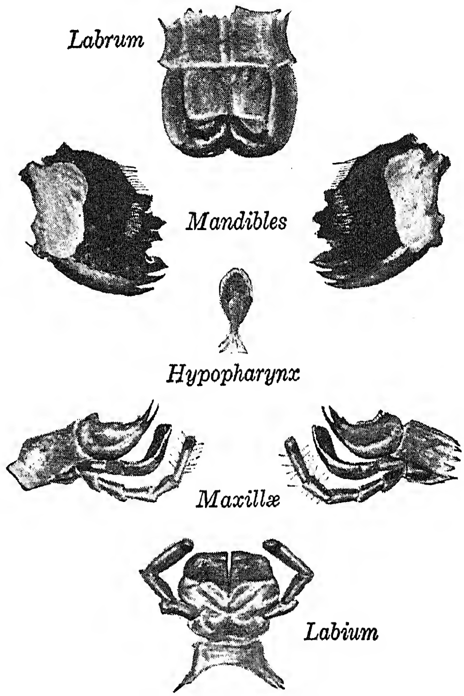


FIG. 1. Mouth parts of red-legged grasshopper. (×4)

The *mouth* of the grasshopper is on the ventral, or lower, surface of the head. It is surrounded by a number of structures, together known as the *mouth parts* (Fig. 1). These consist of a flap-like upper lip, or *labrum*; a lower lip, or *labium*; a pair of *maxillæ*; a pair of *mandibles*; and a tongue, or *hypopharynx*. The maxillæ are located at the sides of the mouth. Both they and the labium have

short feeler-like organs called *palpi*. The hard mandibles grind the food, which is held and passed in to them by the other mouth parts.

The Thorax. The first somite of the thorax, called the *prothorax* (Fig. 2), bears the first pair of legs. It is free from the rest of the thorax. The dorsal surface (Lat. *dorsum*, "back") is thickened and raised into a ridge, the sides (lateral surfaces) are also thickened, and the whole forms a protective shield or collar. The second somite, the *mesothorax* (Fig. 2), bears the second pair of legs; to the third, or *metathorax*, the last pair of legs is attached. Each leg is composed of a number of divisions, of which the principal are the thick *femur* (Figs. 2, 3) and the spiny *tibia* (Fig. 3). Each leg ends in a series of three small joints, forming the *tarsus*, or foot, the last division of which bears two *claws*, with a pad, the *pulvillus*, between them.

Of the two pairs of *wings* (Fig. 2), the first is attached to the surface of the mesothorax, the second to the metathorax. The anterior pair is somewhat hardened, forming protective covers for the more delicate posterior wings, which are folded like a fan beneath them. The latter only are used in flight. The wings are simple extensions of the body wall, and not jointed appendages like the legs. On the sides, just beneath the posterior edge of the collar on the prothorax, is a pair of breathing openings, or *spiracles* (not shown in the figure). Two spiracles are placed just above the junction of the second pair of legs (Fig. 2), and the abdomen bears eight pairs along the sides.

The Abdomen. The first abdominal somite is much larger than the others, though it does not form a complete ring, owing to the space occupied by the cavities for the attachment of the hind legs. Each side of this somite bears an oval spot consisting of a thin skin stretched across a small cavity and connected with a nerve, the whole forming an

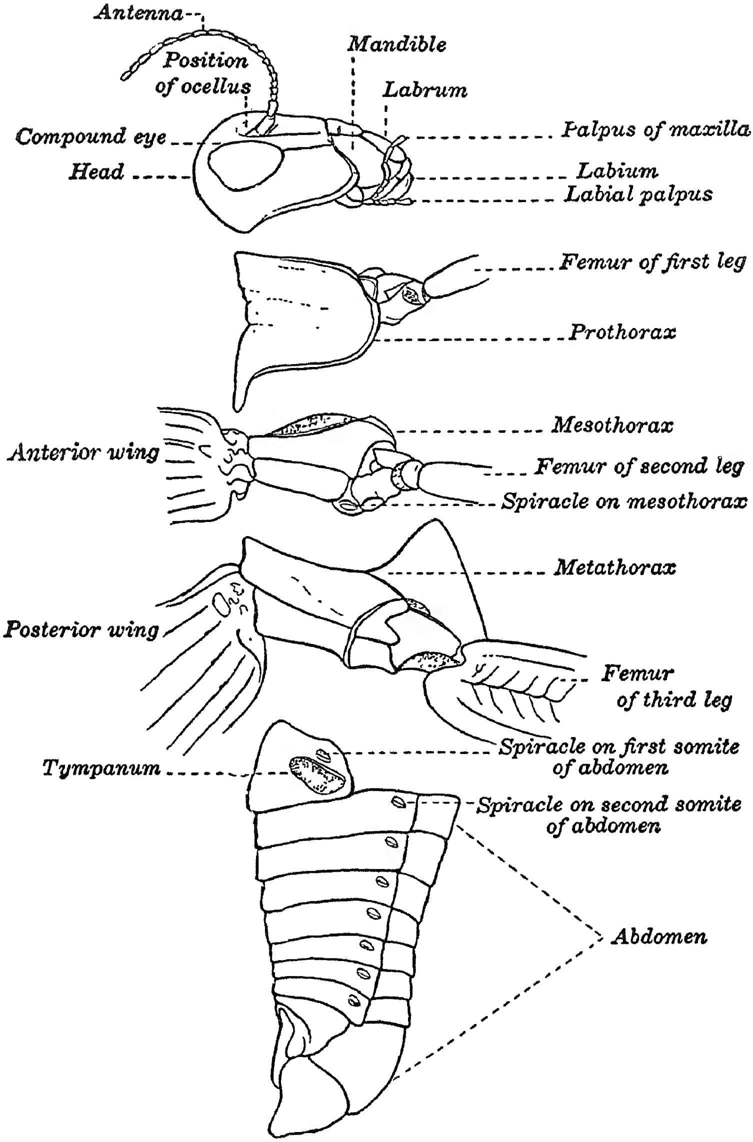


FIG. 2. External parts of male grasshopper. (× 4)
After Kingsley

ear, or *tympanum* (Fig. 2). The end of the abdomen in the female is more tapering than in the male, and is furnished with two pairs of blunt spines, which form an egg-laying instrument, or *ovipositor* (Fig. 3).

The Digestive System. After this brief review of the main features of the external anatomy, or structure, of the grasshopper, we turn our attention to the organs of the interior. And first, owing to its size and the ease with which its parts may be examined, we may consider the digestive system. The function of the digestive system of an animal is to prepare the food for use by the different organs of the body. In the grasshopper the organs of digestion are the food tube, or *alimentary canal,* and its accessory organs, the *salivary glands* (Fig. 3) and *gastric cæca* (gastric, pertaining to the stomach; *cæca,* plural of *cæcum,* a pouch or cavity open only at one end).

The alimentary canal is a long tube extending through the body and variously modified in the course of its extent. The first division is the *mouth,* guarded on each side by the laterally moving mandibles. Between the mandibles, and arising from the inner surface of the labium, is a short, brown, tongue-like organ, the *hypopharynx* (Figs. 1, 3). At the base of the hypopharynx opens the tube from the several pairs of salivary glands. A portion of the slightly convex surface of the inner side of the labrum is the *epipharynx,* the seat of the sense of taste.

Beyond the mouth the alimentary canal continues as a short, curved *esophagus* (Fig. 3), which leads to a large *crop,* armed with rows of spine-like teeth. Posterior to the crop is a very small *gizzard,* also furnished with spines, opening directly into a large, thin-walled *stomach* (Fig. 3). At the anterior end of the stomach are attached the six tubular gastric cæca, closed at one end but opening into the stomach at the other. Beyond the stomach the alimentary canal

continues as a slightly coiled tube, the *intestine,* and ends posteriorly at the *anal opening* (Fig. 3).

The functions of these different parts are as follows. The food, after being crushed by the mandibles and moistened by the saliva, enters the crop, where it is subjected to the action not only of the saliva but also of a fluid from the gastric cæca. The "molasses" thrown out from the mouth as a defensive fluid by the grasshopper, when handled, consists of partially digested food from the crop, mixed with the digestive fluids. When sufficiently dissolved and changed chemically, the food filters through the spines of the gizzard into the stomach, where it is further acted upon by another digestive fluid. The thin walls of the stomach allow the prepared food to pass through and mingle with the blood in the general body cavity. This process is called absorption. The anterior part of the intestine is thin-walled, and absorption may take place there and also in the cæca. The unused food material passes from the body by way of the anal opening.

The Circulatory System. When the food has been acted upon by the various digestive fluids, and so changed that it may be used to supply the different organs with nourishment, it is distributed over the body by the circulatory system. At the same time certain waste matters are taken away and carried to organs which remove them from the body. In the case of man and many other animals, the circulatory system is also the means by which oxygen is carried to all the organs; but, as we shall see in a moment, this work is otherwise provided for in the grasshopper. As soon as the prepared food has been absorbed by the walls of the stomach and intestine it mingles with the blood, which flows through the body cavity in *sinuses* (spaces between the various organs), though not in definite blood vessels. The *blood* is propelled by a tubular, pulsating vessel, or *heart*

(Fig. 3), which extends through the abdomen just beneath the dorsal surface. On account of its position in the body it is often spoken of as the *dorsal vessel.* The heart is prolonged anteriorly into a tube leading to the head, and is partially divided by valves into eight chambers, which permit the movement of the blood only from the posterior to the anterior end. When the blood has been passed out into the general body cavity, it returns through a closed tube (*ventral sinus*) between the muscle masses lying in the lower (ventral) part of the body, and reënters the heart through side openings.

The Respiratory System. The function of the respiratory system is to provide for a constant supply of oxygen for all the organs of the body and to remove waste material, chiefly carbon dioxide. This is accomplished by a system of tubes, called *tracheæ,* communicating with the surface by the spiracles of the thorax and abdomen. The tracheæ are connected and form a network of tubes running to all parts of the body, even out into the legs and wings. They are also in connection with a system of large *air sacs* (Fig. 3) extending through the body. The tracheæ are kept permanently open by a spiral thickening of their chitinous lining, so that air may enter freely at all times. Air is drawn into and forced out of the tracheæ by rhythmic contractions of the body. A constant supply of oxygen is thus assured and carbon dioxide is expelled. The completeness of the respiratory system in the grasshopper is in striking contrast to the undeveloped character of the circulatory system.

The Excretory System. The union of the oxygen taken in during respiration with the carbon in the body produces carbon dioxide, — a waste product. This leads us to consider the organs which assist in the removal of materials which have helped to build up the body substance and have become so changed chemically that they are no longer useful.

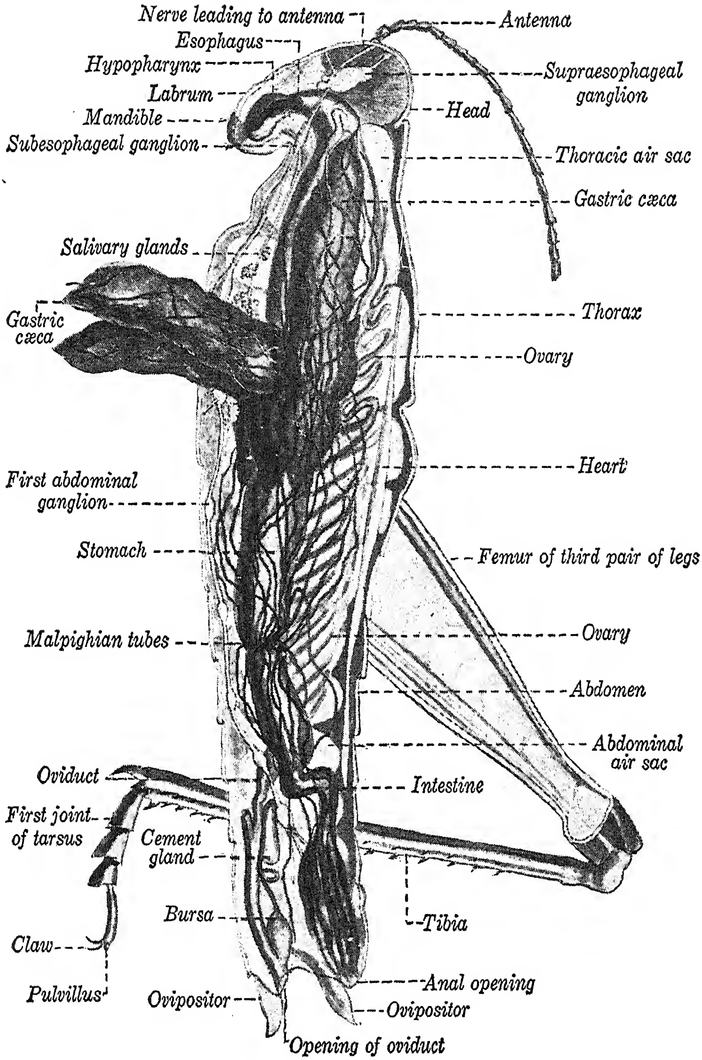


FIG. 3. Dissection of the common red-legged grasshopper (*Melanoplus femur-rubrum*). (× 4)

Such organs are termed organs of excretion. Besides carbon dioxide, important excretory products are water and various substances containing nitrogen, hence called nitrogenous wastes. The two latter classes correspond to the material removed by the kidneys of the higher animals.

Very little is known of the process of excretion in insects. It has been generally believed that the carbon dioxide finds its way to the surface through the tracheæ. In some cases it probably escapes through the skin. Water and the nitrogenous wastes are removed by *malpighian tubes* (Fig. 3), which form so prominent an object when the body of the grasshopper is first opened. They ramify through the body cavity and open into the alimentary canal at the junction of the stomach and intestine, their contents passing to the outside with the undigested food in the intestine. This undigested food is not an excretion, using the word in the sense defined above, since it has never formed a part of the body substance. It has been suggested that as the chitinous covering of insects is largely made up of carbon and nitrogen, the frequent casting of the skin (molting) may be an act of excretion of considerable importance before the insect reaches its adult state.

The Nervous System. All the processes just described, even the flow of blood and the secretion (formation) of the digestive fluids, are under the control of the nervous system. Through its organs of sense the grasshopper is brought into touch with the outside world; by its control over the muscles, movements are made. The nervous system of the grasshopper consists of a series of connected nerve centers, called *ganglia* (Fig. 3), from which *nerves* are given off to the different parts of the body. There are two kinds of nerves, sensory and motor; the former carry messages from the various sense organs to the ganglia; the latter carry impulses from the ganglia, which result in the contraction

of muscles and movements of the various organs, or of the body as a whole.

The largest ganglion is in the head, and is generally called the "brain," or, because of its position just above the esophagus, the *supraesophageal ganglion* (Fig. 3). From this ganglion pass the nerves which go to the eyes, antennæ, and labrum. Two cords encircling the esophagus pass to the next ganglion, which, owing to its position just beneath the esophagus, is called the *subesophageal ganglion* (Fig. 3). This ganglion sends nerves to the mandibles and maxillæ. The supraesophageal and the subesophageal ganglia preside over and coördinate the various general movements of the grasshopper's body. It has been shown that an insect may live for months with the anterior of these ganglia destroyed, if the other is not injured. The insect will feed if food is placed to its mouth, but it loses the power to go in search of food. Of the other ganglia three are in the thorax and five are in the abdomen, forming a median chain resting on the ventral surface of the body cavity. These ganglia are centers for the control of movements and respiration in the somites to which they belong.

The Muscular System. All the *muscles* of the body are supplied with microscopic nerves. The muscles are attached to the hard covering of the body, and when stimulated by the nervous system they contract, thus moving the part to which they are attached. Though delicate in appearance the muscles are in reality very strong, as may be understood when the activity of the insect is considered.

The Reproductive System. As in most other animals, the union of two dissimilar elements is necessary for the production of a new grasshopper. These elements are the very small, active *sperm cells* produced by the male, and the much larger *egg cells* produced by the female. The reproductive cells are produced in special organs called *gonads.*

On the union of these two cells the egg cell is said to be fertilized, and the growth of a new individual is begun. Occupying a considerable part of the posterior portion of the abdomen of the female are the *ovaries* (Fig. 3), two sets of delicate tubular organs, in which the egg cells are developed. These are connected with the surface by the egg tube, or *oviduct* (Fig. 3). In the male the sperm cells are formed in organs called *spermaries*, a tubular mass in the third,

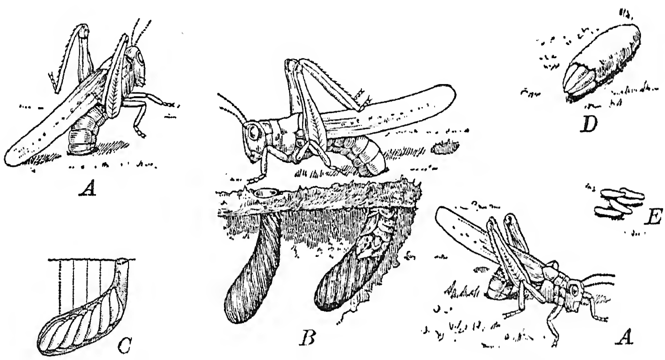


FIG. 4. Rocky Mountain grasshopper laying eggs. (About natural size)

A, B, female laying eggs; *C,* diagram showing the arrangement of eggs in the hole; *D,* mass of eggs removed from hole and part of covering taken away; *E,* few eggs separated. (After Riley)

fourth, and fifth abdominal somites. After fertilization the eggs are covered on the way down the egg tube by a sticky substance poured out from the *cement gland* (Fig. 3). This gland opens into an enlarged pouch, or *bursa* (Fig. 3), which rests on and opens directly into the oviduct.

Development. The eggs of the red-legged grasshopper are laid in the autumn in holes made by the ovipositor of the female, in the ground of fields, pastures, and waysides. They differ in no important respect from the eggs of the Rocky Mountain grasshopper shown in Fig. 4. Each hole contains from twenty to thirty-five eggs. A secretion from

the gland already mentioned binds all the eggs in a single hole into one mass, and when the number is completed more fluid is poured out, which hardens into a firm covering. Here they remain over the winter and hatch out into young grasshoppers in the spring, quite closely resembling the adult except in absolute and relative size of parts and in the absence of wings. They grow rapidly, molting several times during the summer, appearing each time a little larger. While these changes are going on the young grasshopper is called a *nymph* (Fig. 5, *A–E*). The last molt takes place late in the summer. The nymph climbs up some grass stem or similar object. Taking firm hold, often with its head pointing downward, it remains motionless for several hours, till the skin swells over the head and thorax and finally splits open along a me-

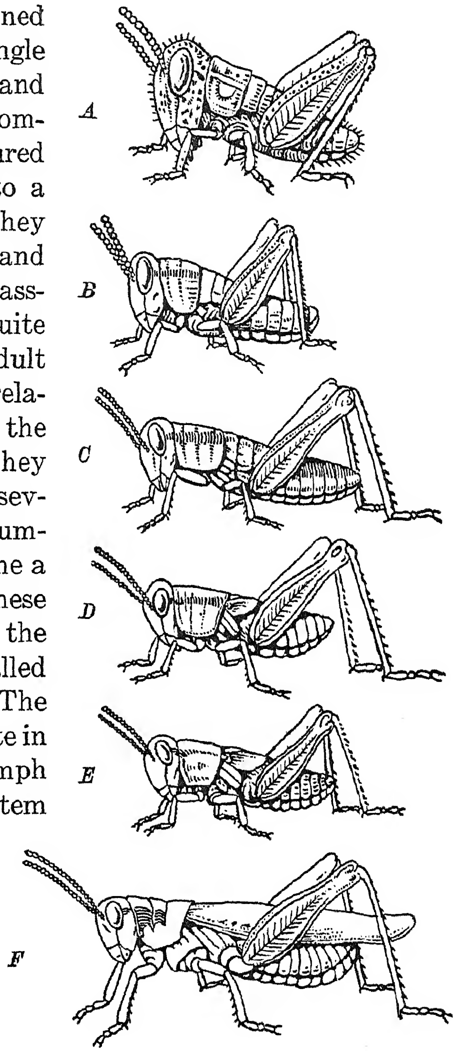


FIG. 5. Development of grasshopper
A × 6, *B* × 2, the others slightly enlarged[1]

[1] From Packard's *Text-Book of Entomology*.

dian dorsal line. From this old skin the new head, thorax, legs, wings, and abdomen are slowly withdrawn while the new skin is still very soft. The body and all its appendages expand and harden within half or three quarters of an hour. It is now an adult insect, or *imago*, of full size and with fully developed wings, which up to the last molt have been of no use to the grasshopper.

Relation to Environment. Red-legged grasshoppers are found in meadows, pastures, fields, and along roadsides, though most abundant where the vegetation is succulent. Specimens from low, damp ground are usually somewhat darker in color than those from high, dry areas. Their food consists of the leaves of grasses and other vegetation. The strength of the mandibles and the complexity of the digestive system fit them admirably for a life of constant forage. Their color is, to a certain extent, protective, for they are not easily seen among the dried grasses of the summer.

Grasshoppers have, when adult, three methods of progression, — walking, jumping, and flying. The many spines pointing downward on the legs and the pulvilli between the tarsal claws make climbing an easy matter.

The list of the grasshopper's enemies is long and formidable, even if man is not considered. Small animals, such as moles and birds, especially the crow and blackbird, feed on the eggs and the young. Some species of wasps use the nymphs to provision their nests, first stinging them to render them helpless. They are also subject to a disease caused by a fungous growth, and may often be found firmly attached to some grass blade to which they have clung before death. That they have been able to maintain themselves in such large numbers in spite of all their enemies, marks them as successful competitors in the struggle for existence.

CHAPTER II

THE ALLIES OF THE RED-LEGGED GRASSHOPPER: ORTHOPTERA

The poetry of earth is never dead:
When all the birds are faint with the hot sun,
And hide in cooling trees, a voice will run
From hedge to hedge about the new-mown mead;
That is the Grasshopper's — he takes the lead
In summer luxury, — he has never done
With his delights.

KEATS

The Rocky Mountain Grasshopper. Though the common red-legged grasshopper is widely distributed throughout the United States, it has not attracted so much attention as the Rocky Mountain grasshopper, for its effects on agriculture have not been so marked. The latter has the remarkable habit of migrating from its habitat on the dry plains east of the Rocky Mountains, destroying in a few hours the labors of the farmer for several months. Not only are growing crops devoured, but every green thing is attacked, leaving the country as bare as if a fire had swept over it. The grasshoppers show a tendency to become gregarious (having the habit of associating in groups) from the beginning of their life as nymphs, but their migrations are not generally begun before they are at least half grown. These hordes proved so destructive to the agricultural district of the Middle West from 1873 to 1877 that a commission was appointed by the government to study their habits and to report upon ways and means for checking their devastations.

Control of Grasshoppers. Many machines have been constructed to capture the various kinds of grasshoppers when

they become abundant enough to threaten cultivated crops. One of the commonest of these is called the hopperdozer. As this is dragged across a field the grasshoppers start to fly or jump but strike an upright wall and drop into a trough filled with oil.

Since grasshoppers are chewing insects, one of the best means of exterminating them is by use of sweetened poisoned bran, which they eat in preference to the vegetation. In years when they are abundant many millions of dollars worth of grain are saved annually by poisoning and by capturing the swarms of grasshoppers invading the fields.

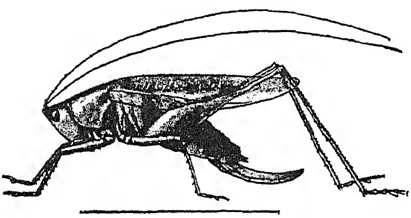


FIG. 6. A meadow grasshopper

From the Illinois State Natural History Survey

Grasshoppers in History. There are several species of migratory grasshoppers in the Old World whose visitations in the past have been destructive, especially in Egypt, Palestine, Syria, Asia Minor, China, Russia, France, and Germany. The prophet Joel has described the onslaught of grasshoppers in the lines beginning

> A day of darkness and of gloominess, a day of clouds and of thick darkness, as the morning spread upon the mountains: a great people and a strong; there hath not been ever the like, neither shall be any more after it, even to the years of many generations.[1]

It is easy to appreciate the fact that in thickly settled areas famine and pestilence may follow the visitation of these insects. Out of the twelve hundred or fifteen hundred species of grasshoppers in the world, only about twelve have the habit of migration to any great extent, and these are mostly

[1] Joel ii, 2.

species which live on large, elevated, open tracts of desert or semidesert character, where the climate is dry and hot, — for example, such regions as the steppes about the Caspian Sea. Perhaps the determining factor in the migration is excessive multiplication and the consequent need for new feeding ground.

Grasshoppers have been and are used today as food in various parts of the East. The records on the bricks of Babylon and Nineveh show that they were known in early

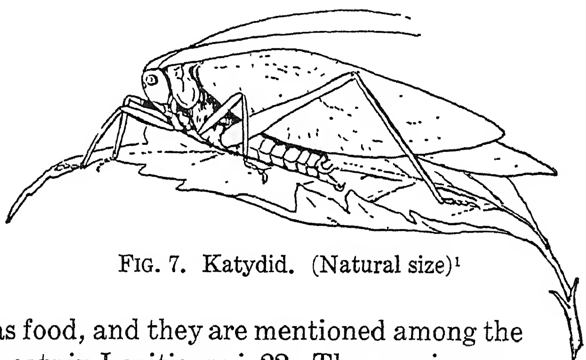


FIG. 7. Katydid. (Natural size)[1]

times as food, and they are mentioned among the clean meats in Leviticus xi, 22. They are in common use among the Arabs and the Bushmen; our own Rocky Mountain grasshopper has been eaten and pronounced quite palatable.

Sounds. Many grasshoppers produce sounds by rubbing the inner edge of the posterior femur against the outer edge of the first pair of wings. Some grasshoppers produce a noise in flight by the friction of the wings.

Long-Horned Grasshoppers. In contrast to the grasshopper described in the last chapter there are others which have very long antennæ and are therefore called long-horned grasshoppers (Figs. 6, 7). These have thread-like antennæ, much longer than the body. Perhaps the most interesting

[1] From Hunter's *Studies in Insect Life.*

are the katydids (Fig. 7), large green insects of arboreal (tree-dwelling) habits, found in the eastern and central United States. They afford an illustration of *protective resemblance,* — a term which is used to cover those cases in which an animal possesses colors or shape which harmonize with its environment (surroundings), or with some particular object in the environment, thus affording protection against enemies. In the case of katydids the whole body is green and the wings are thin and veined like a leaf. The well-known note from which the name "katydid" is derived is produced only by the male, and is made by rubbing the base of one of the first pair of wings against the other anterior wing. An auditory apparatus is found in both sexes at the base of the front tibiæ, not on the abdomen as in the short-horned grasshoppers. The female has a long sword-like ovipositor (Fig. 6) with which the eggs are thrust in overlapping rows into the bark of twigs. The common meadow grasshopper (*Orchel'imum,* Fig. 6) gives a good idea of the appearance of a long-horned grasshopper.

Crickets. The crickets (Fig. 8, *A*) resemble the grasshoppers in the possession of long, slender antennæ, but differ from them in having the anterior wings overlapping, instead of meeting in a ridge along the median line of the back. They are widely distributed over the earth, and are, as a rule, nocturnal in their habits. They feed mostly on vegetable matter, though at times they destroy clothing. Our native species live in the fields beneath sticks and stones. The house cricket of Europe (*Gryl'lus domes'ticus*) has spread into many parts of the United States. This is the species famous in song and story. Its well-known chirp is made only by the male. The principal vein on the ventral surface of each anterior wing is thickened into a rasp-like structure (Fig. 8, *B*); on another part is a hardened portion called the scraper. The noise is produced by raising

the anterior wings and rubbing the rasp of the right wing against the scraper of the left. Fig. 8 shows one of the species common in the eastern United States.

The mole crickets (*Gryllotal'pa,* Fig. 9) are burrowing insects, which show interesting adaptations to subterranean

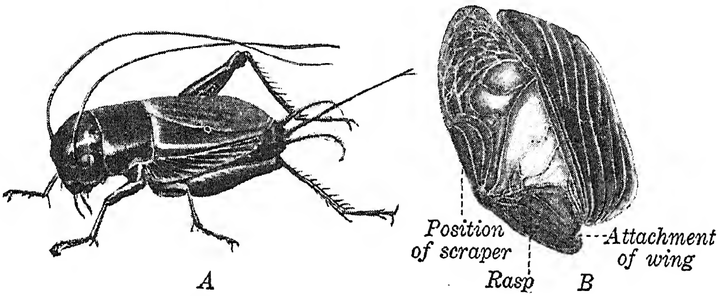


FIG. 8. Cricket

A, female (natural size); *B*, under surface of right wing of male, showing structures for producing sound

life. The fore legs are thickened and adapted to burrowing. Roots are easily cut in two by means of a shear-like motion of the joints of each front tarsus against the teeth of the tibia of that leg. For this reason mole crickets, when numerous, are sometimes a serious pest. The female mole cricket watches over her eggs and, when they are hatched, feeds the young till the first molt. Mole crickets are found both in America and Europe.

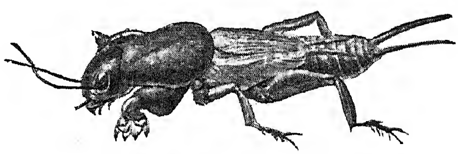


FIG. 9. Mole cricket. (Slightly enlarged)

Cockroaches. The cockroaches are cosmopolitan forms, some of which infest our houses, where they feed on both animal and vegetable matter. They are dark-colored, flattened insects, which depend upon their legs for escape, although

most of them possess wings. The legs are adapted to running. There is no development of strong jumping legs as in the grasshopper and cricket. Their flattened bodies make it easy for them to hide in crevices, whence they come out at night to feed. They usually have a bad odor, and frequent

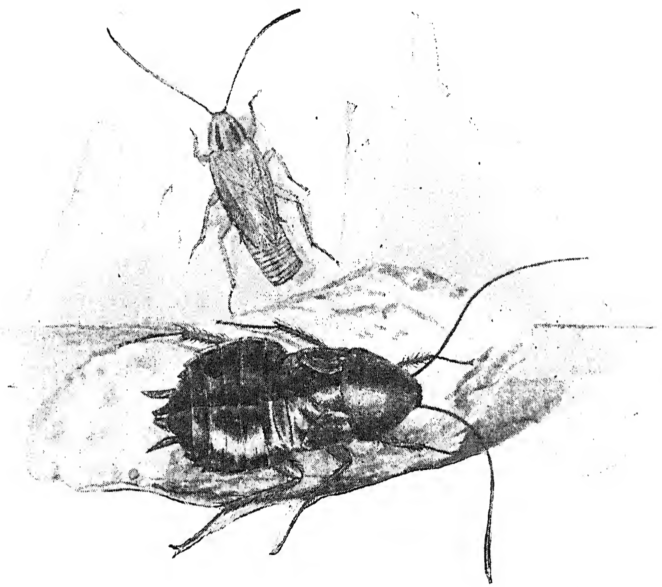


FIG. 10. Cockroaches. (Natural size)

all sorts of filthy places. The female carries her eggs about with her in a large case till the young are nearly ready to appear. Fig. 10 shows the German cockroach, or "Croton bug" (*Blattel'la german'ica*), with its egg case, and a larger species, the so-called Oriental cockroach (*Blat'ta orienta'lis*), though there is little evidence to show its original home.

Walking Sticks. The peculiar insects called walking sticks are also related to the grasshoppers. Among them are some of the most remarkable illustrations of protective resemblance known in the animal kingdom. The common species in the

eastern United States (*Diapherom'era femora'ta*) is shown in Fig. 11. The body and legs are elongated to such an extent that when at rest the resemblance to a twig is most striking. The insect undergoes a seasonal change of color, being brown when first hatched, turning green after feeding, and changing to brown again as the season advances. This walking stick is a voracious feeder on the leaves of trees. One of the longest insects now living is a walking stick from Africa, which has a body about ten inches long.

FIG. 11. Walking stick. (About one half natural size)

Closely related to the walking sticks are the peculiar East Indian insects known as walking leaves. In these insects the anterior wings of the female are green and veined like a leaf. The people in the countries where they are found believe that these insects are really transformed leaves. The males are entirely different from the females, having anterior wings which have no leaf-like appearance.

Mantids. The mantids are remarkable for the development of the fore legs, which are unusually large and strong and armed with stout spines. The function of these legs is to seize and hold living prey, which consists of other insects. When the mantid is lying in wait the fore legs are held up in the air, but when an insect comes within reach they are extended with swiftness and precision. The eggs of the

mantids are deposited in a mass of foam-like matter, which the female discharges from the tip of the abdomen. This material soon hardens and forms a protecting case for the eggs.

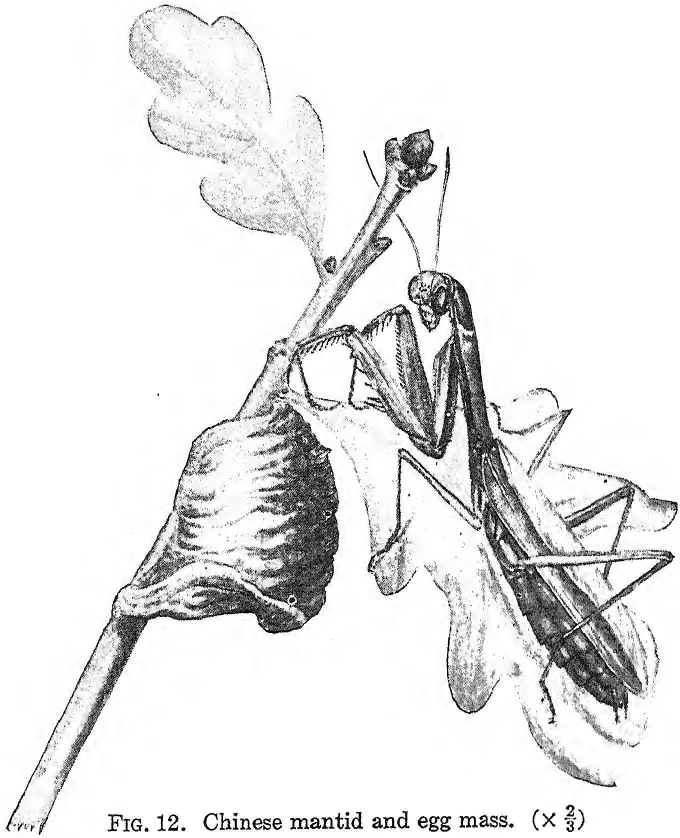


FIG. 12. Chinese mantid and egg mass. ($\times \frac{2}{3}$)

The mantid shown with its egg case in Fig. 12 is a Chinese species (*Paratenode'ra sinen'sis*), which has been introduced in a number of places in the United States. The color is brown and is to some extent protective. Since this inconspicuous coloration may render it easier for the insect to

approach its prey or to escape notice while waiting for food, it may be classed as an example of *aggressive resemblance.* This term covers those cases where an animal, in resembling its immediate environment, either in shape or color, or both, is thought thereby to be assisted in attack on its prey.

Several species of mantids from India resemble different flowers which are visited by insects, and seize upon such unwary visitors as do not detect the imposition. In this case the resemblance is to an object attractive to the prey, and may be spoken of as *alluring coloration.*

Definition of Orthoptera (Gr. *orthos*, "straight"; *pteron*, "wing"). All the insects mentioned in this chapter have the mouth parts adapted to chewing, and most of them have two pairs of wings. The posterior wings, when present, are folded lengthwise like a fan beneath the hardened anterior wings, and are thus protected from injury.

The newly hatched individual grows to the adult condition without any abrupt or conspicuous changes in form. There is an evident increase in size each time the skin is shed in the process of molting. The imagoes differ from the nymphs chiefly in their larger size and the presence of wings. This type of development in which the newly hatched young gradually changes or transforms into the adult is called incomplete metamorphosis. On account of these common characteristics these insects are united in a group, or *order,* called Orthop'tera, in allusion to the longitudinal folding of the posterior pair of wings.

The chewing mouth parts with which the Orthoptera are provided make them especially destructive to vegetation, for they feed very largely on plants. Consequently many members of the group are crop destroyers. Crickets and cockroaches if given the opportunity become serious household pests. Many members of the order seem to have no direct economic importance.

CHAPTER III

THE DRAGON FLIES (ODONATA) AND THE MAY FLIES (EPHEMERIDA)

To-day I saw the dragon-fly
Come from the wells where he did lie.
An inner impulse rent the veil
Of his old husk: from head to tail
Came out clear plates of sapphire mail
He dried his wings: like gauze they grew;
Thro' crofts and pastures wet with dew
A living flash of light he flew.

TENNYSON

Dragon Flies. The dragon flies (*Libel'lula,* Fig. 13) are familiar insects found flying over the surface of still or running water. They feed on other insects, which they capture on the wing. They are lovers of the sunshine, and are most active in the brightest and hottest part of the day. The larger kinds hawk freely over the surface of the water at some distance above it, often far out from the shore, where their range of vision is unobstructed.

It is not uncommon to find them coursing through the air in fields and cities some distance from water. The smaller and weaker kinds keep closer to the shore and the protection of vegetation. All are voracious feeders, destroying large quantities of flies and mosquitoes. Many superstitions have become associated with them in different parts of the country; in the North, where they are popularly called "devil's darning needles," it is believed that they sew up the mouths and ears of children. In the South, where the name "snake feeder" is generally used, they are thought to bring dead snakes to life. It is, perhaps, needless to say that

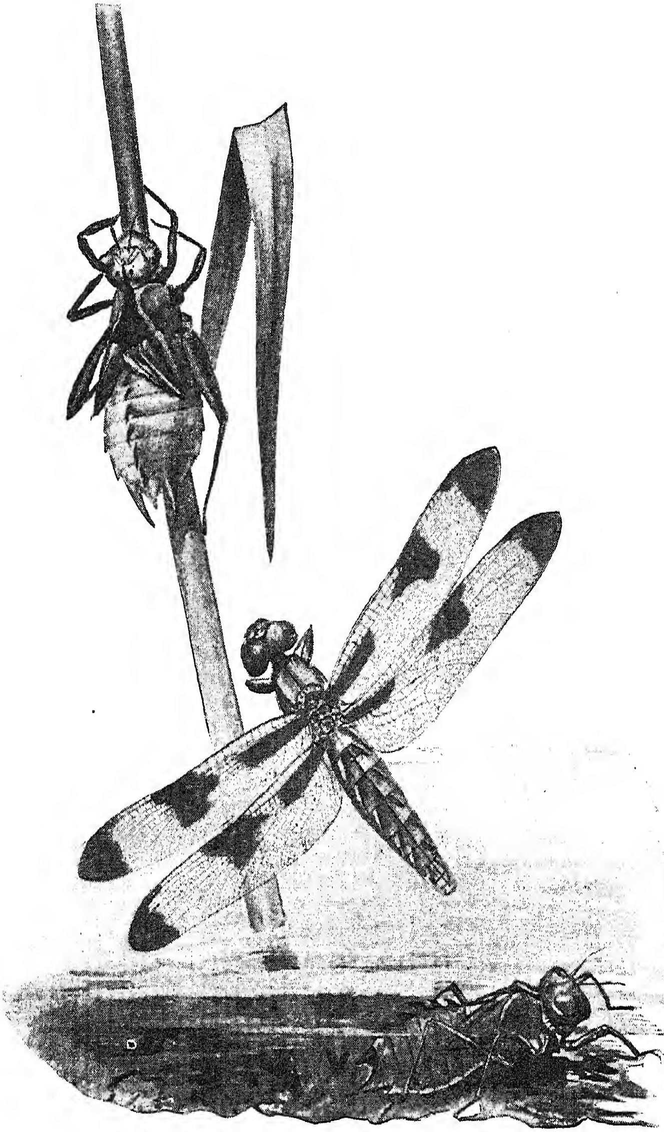


FIG. 13. Dragon fly. (Natural size)
Nymph in water, nymph skin from which adult has emerged hanging to stem

they are not only harmless but are even highly beneficial. The head is made up almost entirely of the great, staring, compound eyes, which shine like fire as the dragon fly moves about. The mouth has strong jaws, somewhat resembling the powerful mandibles of the grasshoppers. The wings are large, with many veins, and are moved by powerful muscles; but the legs are slender and small, as the dragor flies are preëminently creatures of the air. The long and slender abdomen is used to balance the insect in its headlong flight.

The eggs, generally attached to water plants, hatch into aquatic nymphs. The mouth parts of the nymphs are unique in structure. The lower lip is enlarged and armed with hooks at the extremity. This formidable organ is hinged and folded, so that it can be extended to seize any insect within reach. When not so engaged it covers the entire face like a mask, giving a peculiar and comical aspect to a front view. The nymphs breathe by means of tracheæ, which line the posterior portion of the alimentary canal. When water is drawn into the canal, air is absorbed from it by this system of air tubes, and water, deprived of its free oxygen, is forced out again. When water is ejected violently, the nymph darts forward. After successive molts the nymph develops rudiments of wings and finally crawls out of the water to some convenient support, when the skin splits down the back (Fig. 13) and the dragon fly, with crumpled wings, slowly emerges. A short time elapses before the body hardens and the wings expand, and then the imago flies away to live its short adult life.

There are two quite distinct types of dragon flies, both widely distributed over the world. The form represented in Fig. 13 is of comparatively robust build. The eyes touch each other along the median line of the head. The posterior wings are broader at the base than the anterior pair, and both pairs are held horizontally when the insect is at rest.

To this type belong the best fliers of the group. The insects which illustrate the other type, while they can easily enough be recognized as dragon flies, are of more slender build. These are commonly called damsel flies. Their eyes are widely separated on opposite sides of the head. The anterior and posterior wings are alike in size and shape, and when not in use are folded against the abdomen. The flight is less sustained and more erratic than that of species of the first type.

Definition of Odonata (Gr. *odous* (*odont-*), "tooth"). The dragon flies constitute the order Odona′ta, a word meaning "toothed," perhaps in allusion to the teeth on the labium of the nymphs. The Odonata are distinguished by the biting mouth parts and the four equal or nearly equal net-veined wings. Though the nymphs do not closely resemble the adults, there is no conspicuous change from one molt to the next, except at the last molt. Then the fully formed wings of the adult are liberated from the wing pads of the nymph. Although the nymphs resemble the adults less than in the case of grasshoppers the Odonata likewise have incomplete metamorphosis.

> The sun comes forth and many reptiles spawn;
> He sets and each ephemeral insect then
> Is gathered into death without a dawn,
> And the immortal stars awake again.
>
> SHELLEY

May Flies. The May flies (Fig. 14), which stand in literature as the type of brief and purposeless existence, are delicately constructed, pale insects, with usually four finely veined wings and two or three long, white filaments projecting from the end of the abdomen. The eyes are comparatively large, but the mouth parts are so reduced that no food can be taken during adult life, which in most species lasts only a few hours. May flies appear in countless numbers in late spring or early summer, dance about in the air

at dusk in swarms so dense that the atmosphere seems one mass of moving forms, and, after laying their eggs, perish with the day, forming a great food supply for fishes and birds.

The eggs are laid in the water and hatch into nymphs, which do not at all resemble the adult (*Ephem'era,* Fig. 14), but are adapted to an aquatic existence by the presence, along the sides of the abdomen, of outgrowths of the body wall penetrated by tracheæ. These outgrowths are called *tracheal gills.* The delicate skin of which the gills are formed permits the passage of oxygen from the surrounding water inward, and allows the escape

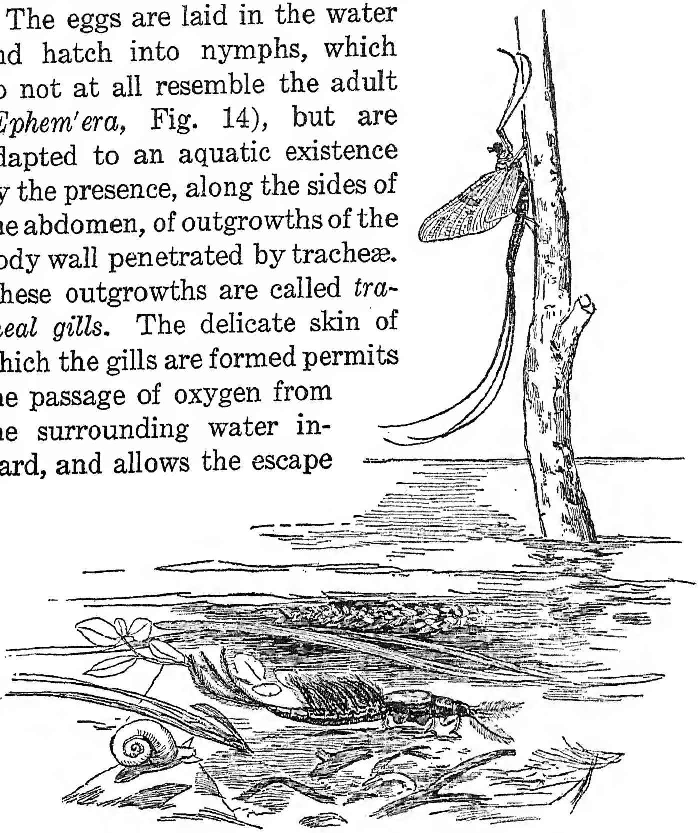


FIG. 14. Nymph and imago of May fly. (Natural size)

of carbon dioxide. The young feed on small aquatic animals or on plants. After a year or more of this life beneath the surface, during that time undergoing many molts, the nymph develops rudimentary wings. From the nymph issues a winged form which may be called a *subimago.*

Within a very short time the skin is again cast, even to a thin covering from the wings, and the true imago comes forth. A molt in the winged state is known nowhere else among insects. Though the reduced mouth parts make it impossible for the adult May fly to take any food, the alimentary canal is not useless. Air is taken in at the mouth, and the capacious stomach acts as a balloon, being provided with valves so that the air cannot escape.

Definition of Ephemerida (Gr. *ephemeros*, "lasting but a day"). The May flies make up the order Ephemer′ida. They may be distinguished from other insects by the two pairs of lace-like wings, of which the hind pair is much the smaller. Three or two fine, hair-like appendages extend from the posterior end of the abdomen. The aquatic nymphs have chewing mouth parts, but in the adults the mouth parts are not functional. From the earliest nymph stages to the imago there is a very clearly marked, though gradual, change or incomplete metamorphosis.

CHAPTER IV

THE CICADAS, PLANT LICE, AND SCALE INSECTS: HOMOPTERA

The shy cicada, whose noon-voice rings
So piercing shrill that it almost stings
The sense of hearing.
ELIZABETH A KERR

Bugs. Though many people call any insect a bug, the term "bug" is correctly applied to the insects belonging to two orders, the Homop'tera and the Hemip'tera. These orders comprise some of the most important insect competitors of man. The insects of these two orders have long sucking beaks in place of chewing mouth parts. They therefore feed upon plant and animal juices instead of solid foods.

Cicadas. There are several species of cicadas in the United States, of which the best known is the periodical cicada (*Tibi'cina septen'decim*, Fig. 15). In the South this species is usually called the thirteen-year locust, while in the North it goes under the name of the seventeen-year locust. Many of the cicadas which appear in the years between the cycles of periodical cicadas belong to different species which in some instances require not more than two years for their complete development. The name harvest fly (Fig. 16) is frequently applied to them. At the base of the abdomen of the male is a "drum," or sound-producing organ, where a high-pitched note is made by the rapid vibration of tightly stretched membranes, somewhat in the way sound may be produced by pushing up and down on the bottom of a tin pan. This note, heard on hot summer days, has been celebrated as the "song" of the cicada since the time of the Greeks.

The female of the periodical cicada lays her eggs in slits, usually in the small terminal twigs of trees. In a year in which these insects appear in large numbers the trees look as if a fire had passed over them and scorched the ends of all the twigs. The eggs hatch in about six weeks, and the nymphs drop to the ground, into which they dig. For a long period of time, thirteen years in the Southern states and seventeen years in the North, they lie in a cell, feeding on the juices of the roots of trees. Early in the summer of the thirteenth or seventeenth year, they rise to the surface, and, clinging to some convenient support (Fig. 16, *A*), cast their last nymph skin (Fig. 16, *B*) to come out as winged

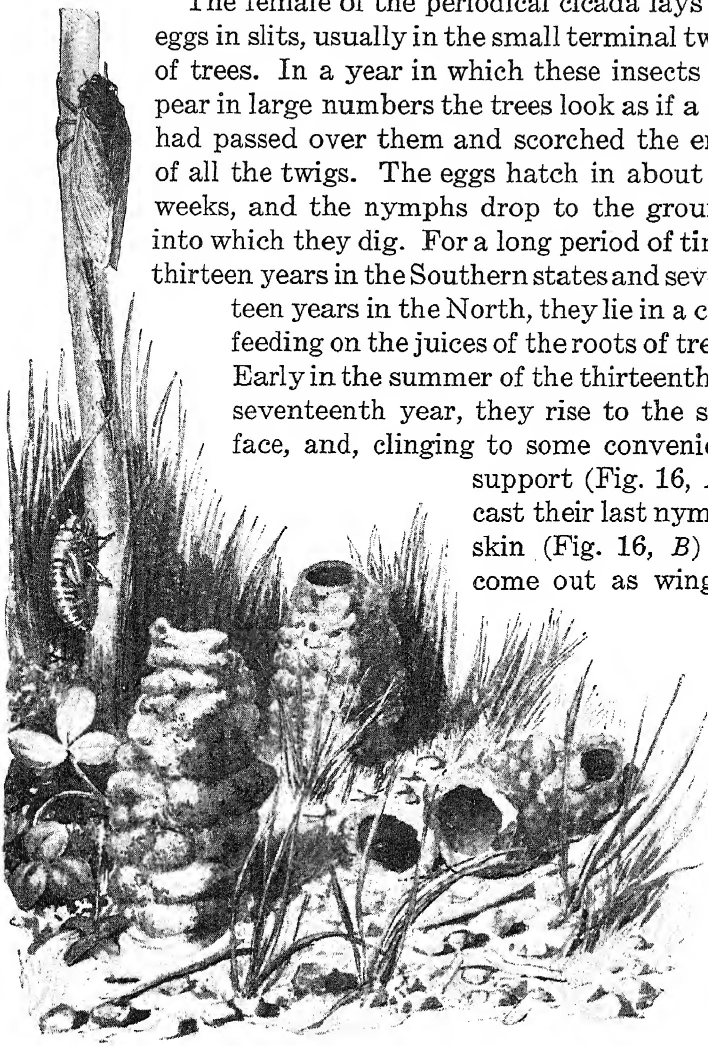


FIG. 15. A study of the periodical cicada. ($\times \frac{1}{2}$)

Female depositing eggs in stem of a plant, nymphal skin from which an adult has emerged, and chimneys

creatures for their few weeks of adult life. In some cases, when the nymphs reach the surface, they build peculiar cones of clay (Fig. 15), several inches in height, over the mouths of their burrows, entirely closing the top of the cone. In the upper part of these they wait the period of their final molt. The formation of these structures has been explained

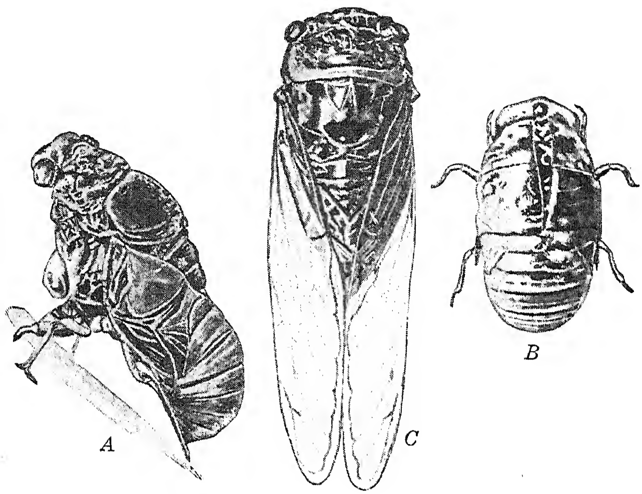


FIG. 16. Harvest fly. (Natural size)
A, adult emerging from nymphal skin; *B*, the cast skin; *C*, adult [1]

by some as due to the prevalence of long-continued wet weather at the time of the emergence; by others, as occasioned by heating of the ground in certain localities by the sun, thus bringing the nymphs to the surface before their time. The cicadas have two pairs of transparent membranous wings. When the wings are at rest they lie along the sides and back of the body like a sloping roof.

Aphids. Everyone who has tried to keep plants indoors must have noticed the small, green, oval insects known as

[1] Reprinted by permission from *Entomology*, by J. W. Folsom, published by P. Blakiston's Son & Co.

plant lice or aphids (Fig. 17). There are many species infesting different plants, upon the juices of which they feed. Some attack the roots, but the greater number are found upon the foliage. They are generally not more than three millimeters (about an eighth of an inch) in length, with a somewhat pear-shaped body, and with or without wings. In most species there is found projecting from the back a pair of slender tubes, which secrete a sticky, waxen substance. This is probably protective in its nature.

FIG. 17. Aphids on grapevine. (Slightly reduced)

Courtesy of the United States Department of Agriculture

One of the most interesting aphids is the one living on the roots of corn (Figs. 18, 19). This aphid (*A'phis maidi-rad'icis*) has become a domestic animal of one species of ant. The cornfield ant cares for the eggs of the aphid in its nest through the winter. In the spring when the young aphids are hatched the ants carry them through underground tunnels and place them upon the roots of weeds. This occurs before the corn is planted. As soon as the corn is sprouted the ants transfer the aphids to the corn roots. There they do much damage sucking the sap. In return for their close attention the ants are paid by securing the honey dew secreted by the aphids.

Very many of our cultivated plants and trees are subject to damage by these insects. On the apple trees

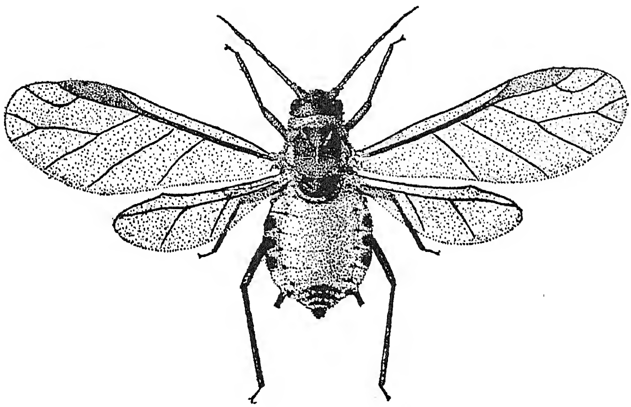


FIG. 18. Aphid with wings. (Much enlarged)
From the Illinois State Natural History Survey

the woolly aphis (*Erioso'ma lanig'erum*) may live either on the roots beneath the ground or on the branches.

In some species the eggs undergo full development within the body of the mother. In such cases the young are born alive and fully formed. Reproduction in such instances is very rapid. The food plant becomes so completely covered that there is scarcely standing room. An aphid colony in the summer may consist almost entirely of wingless females (Fig. 19) which have the power of producing generation after generation of living young without fertilization.

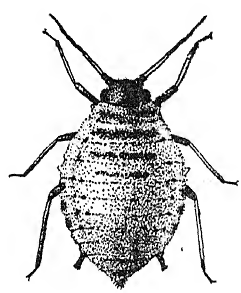


FIG. 19. Wingless aphid
From the Illinois State Natural History Survey

This form of reproduction is known as *parthenogenesis*. The young so produced are females, and many of them are wing-

less, though winged females (Fig. 18) are produced which start colonies in other places, sometimes on a different food plant. Both winged and wingless females are able to produce young parthenogenetically within from ten to twenty days. This kind of reproduction goes on till the approach of cold weather or the failure of the food supply, when males are produced. After pairing, the female lays eggs which last through the winter and hatch into females in the spring. These start new colonies as already described.

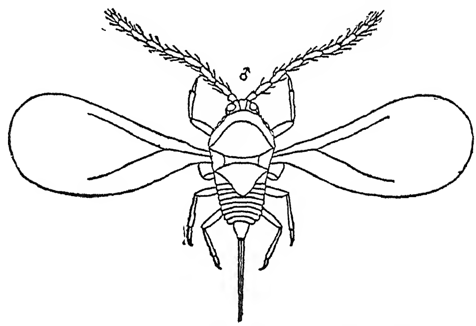


FIG. 20. An adult male scale insect. (Much enlarged)

From the Illinois State Natural History Survey

Scale Insects. Included among the scale insects are some of the greatest enemies to the horticulturist. Almost all kinds of trees and shrubs are subject to their attack. Most of these scale insects become so changed in form (Figs. 21, 22) that they would scarcely be recognized as insects. Ordinarily they become immovably attached to the surface of the plant, from which they draw their nourishment by means of a beak, or sucking tube, thrust permanently into the bark. The back of the insect is covered by a crust-like scale which completely conceals the body. Fixed here permanently, the female produces her eggs or her young, which are at first sheltered by the parent scale. Frequently the male (Fig. 22, *d*) is distinguishable from the female by its smaller size and because it develops in an entirely different manner. In most instances the young wingless females after hatching from the egg soon leave the parent scale.

They settle down at once and form permanent shelters over their backs. Although the male, after hatching, at first resembles the female, it emerges (Fig. 20) from its scale after a time as a free-living, two-winged insect.

FIG. 21. San José scale on young twig

Photograph by the Illinois State Natural History Survey

The San José scale (*Aspidio'tus pernicio'sus*, Fig. 21) was introduced from the Orient into this country about 1886. Since that time it has spread over the entire United States and is one of the most serious menaces to orchards. Tens of thousands of acres of fruit trees have been killed outright by this scale alone.

Oyster-shell scale (*Lepidosa'phes ul'mi*) attacks many shrubs and fruit and shade trees. It reproduces so rapidly that the entire bark becomes incrusted with the scales (Fig. 22, *c*), and the trees soon die unless the scales are killed or removed.

There are hundreds of species of scale insects some of which are limited to a single food plant, although others flourish on a great variety. The cottony scales are especially destructive of shade trees. Oranges and other citrus fruits are attacked by several species, the scales of which are frequently observable on the skins of the marketed fruits.

Early in the history of the invasion of these scale insect pests it was thought possible either to exterminate them or at least to check their spread over the country. This has proved to be impossible. Orchard and shade trees in many

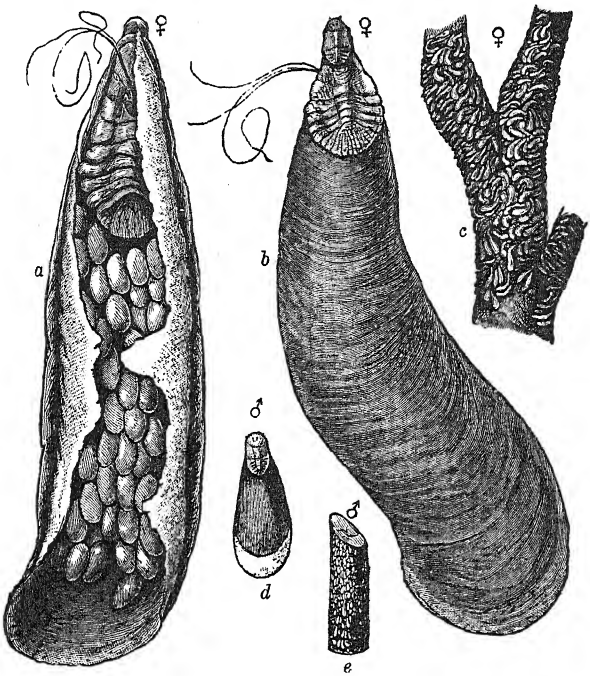


FIG. 22. Oyster-shell scale insect

a, female, from beneath, showing eggs protected by scale (× 24); *b*, female from above (× 24); *c*, female scale on branch (natural size); *d*, male scale (× 12); *e*, male scales on twig (natural size). (After Howard, *Yearbook*, United States Department of Agriculture, 1894)

parts of the country are kept alive only by periodic spraying to kill the scales. Since these are sucking insects, getting their food directly from the sap of the plant, poisons are not available against them. The sprays, to be effective, must on contact kill the insects under the scales.

Man is indebted to some of these insects for a variety o products of greater or less value. One of the scale insect (*Coc'cus cac'ti*), found on the cactus in Mexico, is the sourc of the red coloring matter, cochineal; to another (*Tachar' dia lac'ca*), of India, we are indebted for shellac. The mann mentioned in the Book of Exodus is probably the secretio of a scale insect. It is a sweet substance used today by th Arabs as food.

Definition of Homoptera (Gr. *homo-*, "like"; *pteron* "wing"). The insects belonging to the Homoptera hav mouth parts modified as a sucking beak. In most instance (except in the case of scale insects) there are two pairs o membranous wings arranged as a sloping roof over the back Since the nymphs develop directly into the adults, th Homoptera have incomplete metamorphosis.

CHAPTER V

THE BUGS WITH OVERLAPPING WINGS: HEMIPTERA

> And there's never a blade nor a leaf too mean
> To be some happy creature's palace.
>
> LOWELL

The Squash Bug. The squash bug (*An'asa tris'tis*, Fig. 23), a well-known enemy of squash and pumpkin vines, possesses a beak with which it sucks plant fluids. This bug is a little over two centimeters (nearly an inch) long, and brownish black in color. The two pairs of wings are unlike in structure. The under wings are membranous and delicate, and the outer wings are stiffened at the base and have membranous tips which overlap on the back at the posterior end. The squash bug has the power, in common with many other allied species, of pouring out an evil-smelling secretion from two openings near the base of the middle pair of legs, which probably renders it obnoxious to some creatures which might prey upon it. Observations on the food of birds of

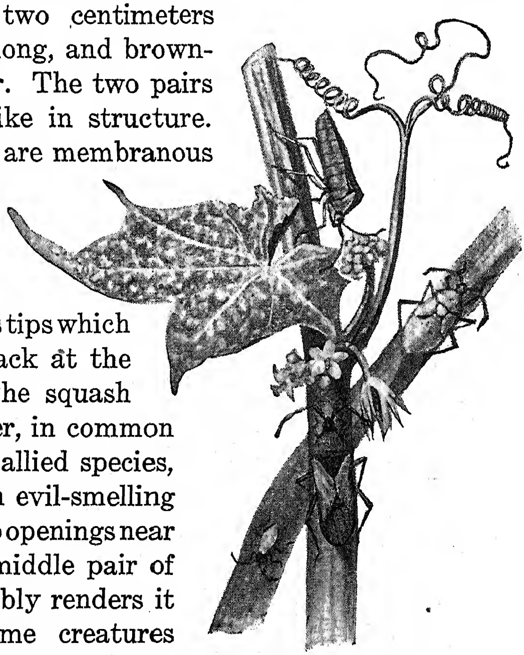


FIG. 23. Squash bug and young. (Natural size)

the eastern United States seem to show that, so far at least as the birds are concerned, these *repellent odors* are not in all cases entirely effective, since many species of plant bugs are fed upon quite generally by various kinds of birds.

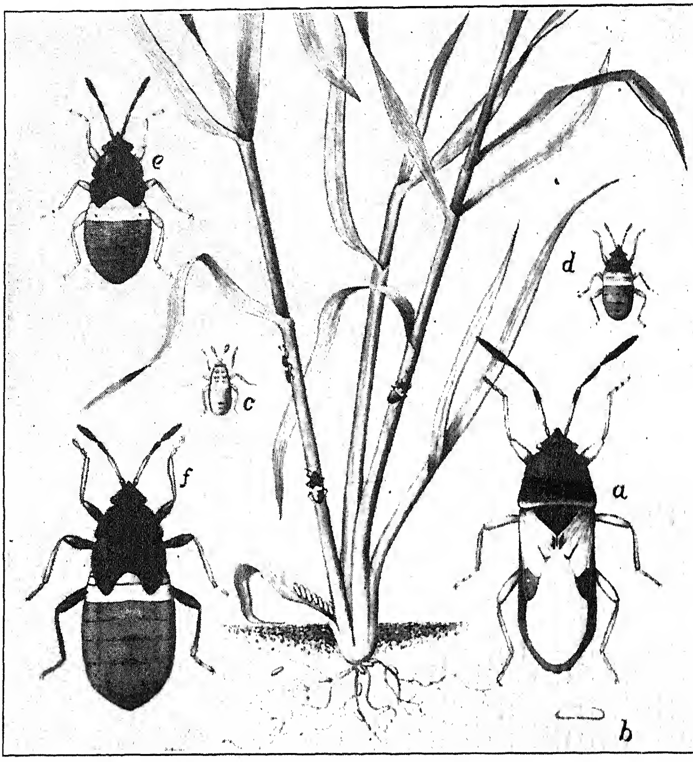


FIG. 24. The chinch bug

a, adult insect; *b*, egg; *c–f*, stages in development of the nymph; wheat plant with eggs on lowermost leaf and with nymphs on stems. (After Forbes)

Chinch Bug. The chinch bug (*Blis'sus leucop'terus,* Fig. 24) is one of the worst enemies of the grain growers of the Mississippi Valley. Agricultural authorities estimated that in one year (1914) the chinch bug alone caused a loss of more

than six million dollars' worth of grain in only thirteen counties in Illinois (see Fig. 62).

Water Bugs. In almost every pond and stream, not only in the United States but almost anywhere on the earth, are to be found oval gray and black insects, usually a little over a centimeter long (about half an inch). These are water boatmen (*Corix'a*, Fig. 25, *B*). They have a long beak. With this they suck the body fluids of other water creatures. They are adapted to rapid locomotion in the water by means of the lengthened and fringed middle and hind legs. They breathe a thin film of air, which is caught in the fine hairs which cover the body, making them look as if incased in polished metal. Slight movements of the legs cause currents of water to pass over this air film, helping to purify it, and making frequent visits to the surface unnecessary. When the boatman is at the surface, air is taken into a cavity under the wings, where the spiracles are placed, so that quite a supply is on hand at all times. While these insects are thus adapted to water life, at the same time they can fly; and they often leave their native element, especially if it is in danger of becoming dry.

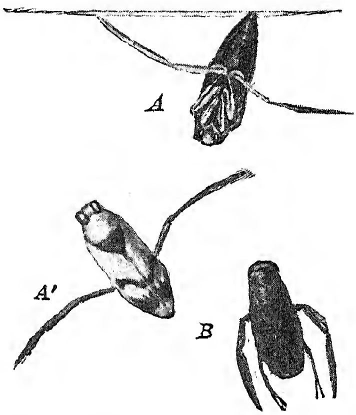


FIG. 25. Water bugs. (All slightly enlarged)

A, back swimmer, ventral view; *A′*, back swimmer, dorsal view; *B*, water boatman

Another widely distributed group of insects resembling the foregoing are the back swimmers (*Notonec'ta*, Fig. 25, *A*, *A′*), which have the curious habit of swimming on their backs, as their common and scientific names denote. A favor-

ite position of these insects is to float with the head down and the tip of the abdomen protruding just enough to admit the passage of air to chambers beneath the wing covers. The back swimmers can inflict a momentarily painful wound with their sharp beaks.

FIG. 26. Giant water bug, or electric-light bug. (Natural size)

The giant water bugs, or electric-light bugs (*Bena'cus*, Fig. 26), are about the largest living Hemiptera. They fly readily from pond to pond and in transit are frequently attracted to electric lights. They become especially important in fish hatcheries and ponds because they attack and kill small fishes, though they also prey upon aquatic insects.

Definition of Hemiptera (Gr. *hemi-*, "half"; *pteron*, "wing"). Members of this order agree in possessing a sucking beak and in having incomplete metamorphosis. Practically all of them have two pairs of wings. The under wings are delicate and membranous, and the outer wings have their bases hardened as a protection to the under wings. On hatching from the eggs the young fairly closely resemble their parents except in size and in lack of wings.

CHAPTER VI

THE BEETLES: COLEOPTERA

Now fades the glimmering landscape on the sight,
And all the air a solemn stillness holds;
Save where the beetle wheels his droning flight,
And drowsy tinklings lull the distant folds.

GRAY, Elegy in a Country Churchyard

More than two thirds of all the known insects are beetles. Obviously no large proportion of these can be included in an introduction to Zoology. The following are a few of the most important.

June Beetles or May Beetles. During the warm evenings of summer there is no more conspicuous insect than the big, blundering, brown beetles (Fig. 27) that swarm about street lamps and batter against our window screens. The hard outer wings, or *elytra*, fit so perfectly over the back that the June beetle (*Phylloph'aga*) seems to be dressed in a complete suit of armor. These elytra meet in a perfectly straight line down the middle of the back. The wings actually used in flying are delicate and membranous. They are so much longer than the elytra that even when the wings are brought into the resting position their tips may stick out untidily from under the elytra until the beetle tucks the ends in place by folding the tips back. Like the grasshopper's the body of the beetle is divided into three regions: the head, thorax, and abdomen. The wings cover the back and sides of the abdomen so completely that the somites are visible only from the ventral surface.

The antennæ are peculiarly constructed. Instead of ending in a single thread-like tip, which usually indicates only

an organ of touch, these antennæ end in a series of flattened leaf-like structures, serving not only as tactile organs but as organs of smell.

The white grubs (Fig. 27) so common in fields and gardens are the young, or *larvæ*, of the June beetles. They feed on roots, sometimes in lawns frequently killing the grass over

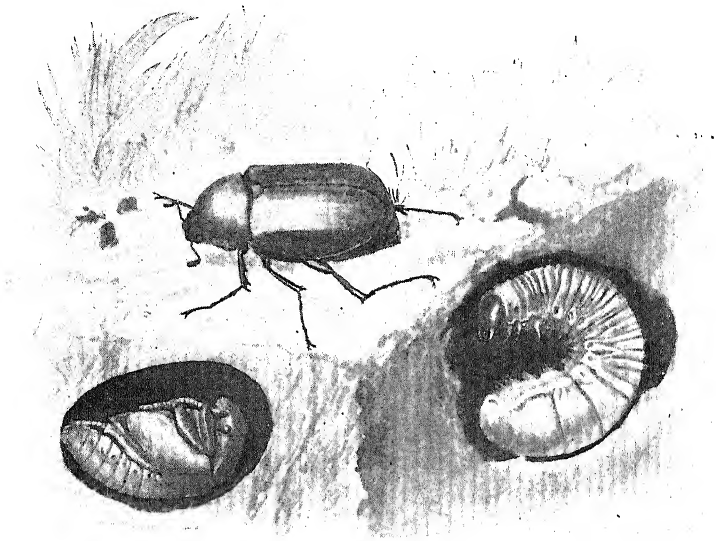


FIG. 27. Adult June beetle, larva, and pupa. (Natural size)

large patches. In truck gardens they do great damage. The adults center their attack above ground, devouring the leaves, particularly of trees. The grub, or larva, when fully grown stops eating and forms a small chamber in the soil (Fig. 27), where it lies inactive. During this resting period the entire body of the grub becomes reorganized. From this resting stage, or *pupa*, the adult beetle finally emerges.

The June beetles belong to that family of beetles known as the scarabs. Certain beetles of this same family have long attracted the attention of observers by their curious

habit of forming and rolling about a pellet of manure for food for themselves or their larvæ. We have several species of these beetles in the United States, but the best known of the group is the sacred beetle of the Egyptians (*Ateu'chus sa'cer*, Fig. 28), the *Scarabæus* of the ancients, figures of which are found carved in stone on the monuments of ancient Egypt. These beetles played an important part in the symbolism of the Egyptians, to whom they typified the

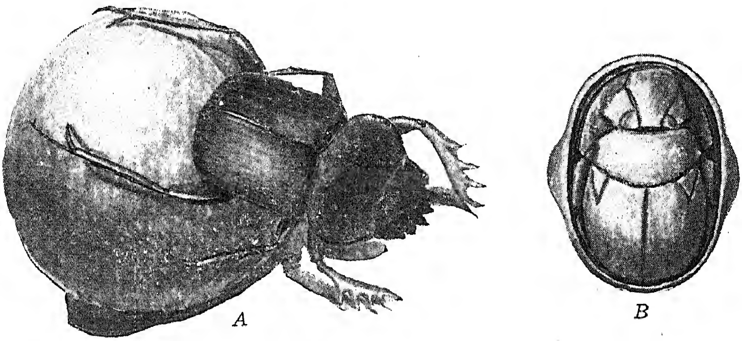


FIG. 28. The sacred scarab. (× 2)
A, beetle with ball of manure; *B*, scarab carved in stone

world and the sun, — the former on account of their round pellets, the latter on account of the projections on the head, which were likened to the rays of the sun.

The Japanese Beetle. One of the best examples that we have of the rapid spread of a newly introduced pest is that of the Japanese beetle (*Popil'lia japon'ica*). Introduced into this country about 1916, probably on the roots of an imported plant, by 1924 it had spread over an area of more than a thousand square miles. Like the June beetle the adult feeds above ground upon the foliage of trees and shrubs, and the grub attacks the vegetation beneath, feeding upon the roots. It is a well-known fact that a destructive animal like the Japanese beetle produces much more

alarming damage in its adopted home, for all its hereditary enemies are lacking. The federal government is spending huge sums of money in an attempt to find natural means of checking the Japanese beetle before it invades the entire country.

Tiger Beetles. The tiger beetles (*Cicinde'la,* Fig. 29) are usually metallic, shining, bright-colored species, about one and a half centimeters in length, with large heads and prominent eyes. They are found on sandy roads or beaches, flying about while the sun shines. Some of them are bright red or green; some are brown or black, with white markings; and others are protectively colored, resembling the sand on which they live. They run swiftly, and when disturbed take flight, only to alight at a short distance, often facing about so that they can better watch the pursuer.

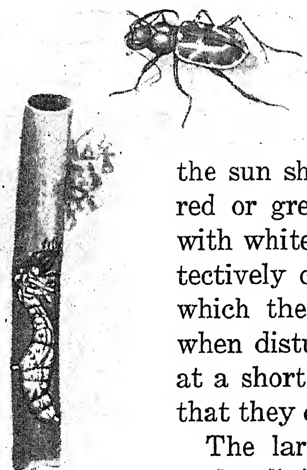


Fig. 29. Tiger beetle and larva. (Natural size)

The larvæ are misshapen, dirty-white grubs, living in holes which they dig in sandy places. Two hooks on the dorsal surface enable them to climb up and down in their holes, which are sometimes thirty centimeters or more deep, and prevent their being dragged out when they have hold of their prey. Here, with the earth-colored head even with the surface, they lie in wait, seizing any passing insect with their strong jaws.

Water Beetles. The whirligig beetles (*Dineu'tus,* Fig. 30) are familiar oval insects found in groups circling about on the surface of still water. They can see both below and above the surface of the water, as the two eyes are divided into four, and the parts separated so that watch can be kept for danger from either direction. The whirligigs are pro-

tected by a strong-smelling milky secretion which probably renders them distasteful to fishes. They are able to dive to escape danger, carrying down with them a small supply of air.

Beneath the surface of such ponds and pools as the whirligig beetles frequent are to be found different species of diving beetles (*Dytis'cus*, Fig. 31), which have adaptations similar to those mentioned among the aquatic Hemiptera. Thus in some the spiracles, which in land insects are along the sides of the abdomen, are here placed beneath the edge

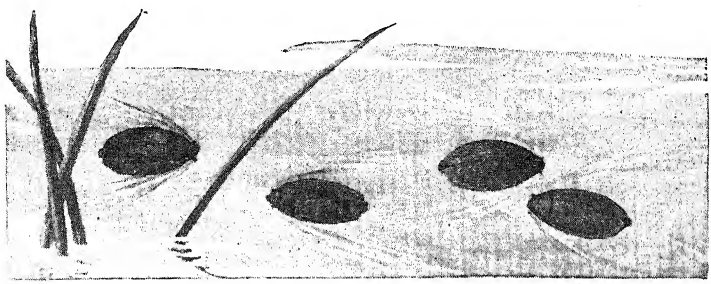


FIG. 30. Whirligig beetles. (Natural size)

of the wing covers on the back, and the space beneath the wing covers is used as an air reservoir, which is replenished with pure air by rising to the surface. In other species a thin coating of air is carried on the under side of the abdomen. This supply is obtained by pushing the head above water and capturing a bubble of air with the antennæ, which are quickly folded beneath the head, carrying the imprisoned bubble to the under surface of the body.

Scavenger Beetles. A useful part in the economy of nature is played by the scavenger beetles (*Necroph'orus*, Fig. 32), large, black, red-spotted insects, which dig beneath the carcasses of small animals, thus burying them beneath the surface. The female then lays her eggs in the decaying material, upon which the larvæ feed until ready to transform.

This exertion removes the carcass from the field of operations of other creatures which might feed upon it, if it were left exposed, and thus destroy the eggs, or larvæ. As these beetles are protected by a fetid odor, their striking markings are usually spoken of as an example of *warning coloration,*

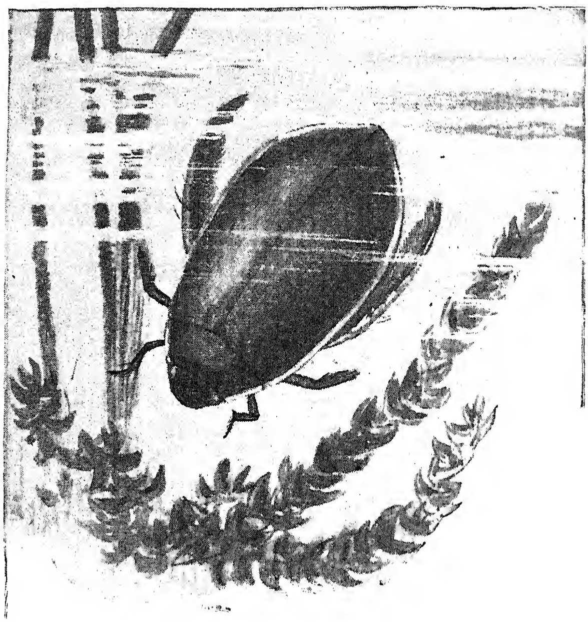


FIG. 31. Diving beetle. (Slightly enlarged)

a term applied to those appearances in animals which are thought to be useful in notifying enemies of the presence of something disagreeable or dangerous.

Lady Beetles. The common and well-known insects variously called lady beetles, ladybugs, or ladybirds (*An'atis*, Fig. 33), are hemispherical in shape and generally reddish or yellowish in color, with black spots. Both the imagoes and larvæ of most species feed upon scale insects, plant lice, and

other insects injurious to vegetation; hence they are to be reckoned among the insects useful to the farmer.

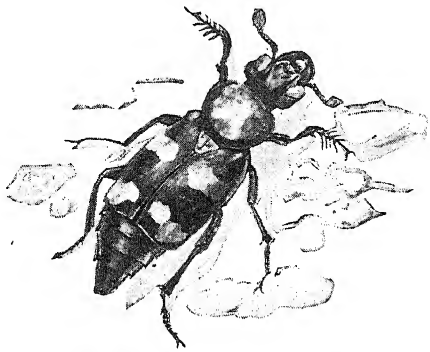


FIG. 32. Scavenger beetle. (Slightly enlarged)

The lady beetles are protected by a yellow, odorous fluid formed in the blood. When the insect is seized the fluid oozes out from the ends of the femora. The bright colors of these insects are usually cited as an example of warning coloration.

Click Beetles. The click beetles are a well-known group, generally brown in color and of elongate form. The species are able to leap into the air when placed on their backs. The mechanism which makes this possible consists of a spine projecting backward on the ventral surface of the prothorax, and a corresponding cavity on the ventral surface of the mesothorax. The larvæ are called wireworms and live in decaying wood or attack the roots of vegetables.

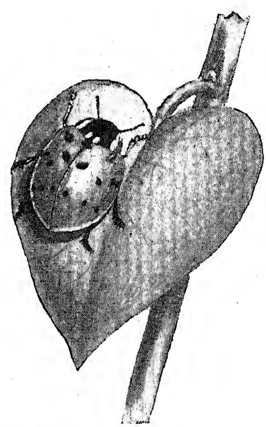


FIG. 33. Lady beetle. (×2)

Fireflies. The flashing lights of the fireflies (*Photi'nus*) on the first warm evenings announce the coming of summer. One would scarcely accept these soft-bodied insects (Fig. 34) as beetles were it not for the way in which the outer wings meet down the middle of the back in a straight line in true beetle fashion.

Fireflies are, for the most part, nocturnal in their habits, clinging to the underside of leaves during the day. They are protected from the insect-eating birds by a strong odor which renders them distasteful. The luminous spots are on various abdominal somites, generally the last. Fireflies appear in greatest numbers in the latitude of the Middle Atlantic states for a week or more in the month of June. Many attempts have been made to account for the light produced by the fireflies. The light-giving organ seems to consist of fat cells inclosed in a network of fine tracheæ. Though the production of light is the result of oxidation, practically no heat is liberated. Thus it is interesting to note that the efficiency of this apparatus as a light-producing organ is close to 100 per cent. In such artificial illumination as a gas jet, for example, only about 2 per cent of the radiant energy consists of light rays. The function of the light of the fireflies is not understood.

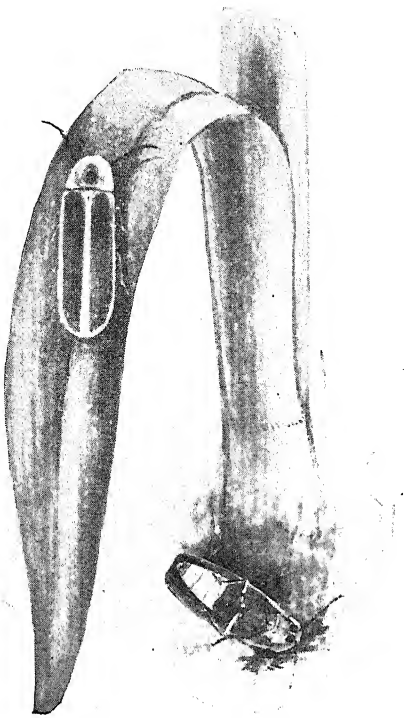


FIG. 34. Firefly. (Slightly enlarged)

The Colorado Potato Beetle. The Colorado potato beetle (*Leptinotar'sa decim-linea'ta*) is well known to every farmer

boy. It is particularly harmful because both the larvæ (Fig. 35, *b*) and adults (Fig. 35, *d*) feed upon the leaves of the potato plants. Originally it was confined to the Rocky Mountain region, where it fed on the wild relatives of the potato. In about 1855 it commenced feeding on the potato plant. It spread so rapidly that in about fifteen

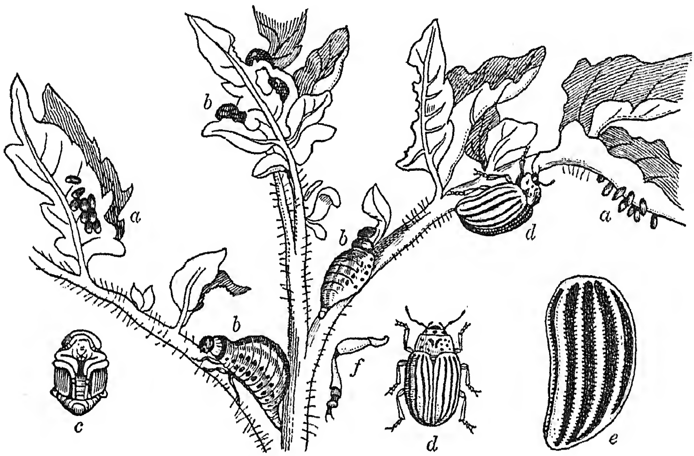


FIG. 35. Stages in the life of the Colorado potato beetle

a, eggs on leaf; *b*, larvæ; *c*, pupa from soil; *d*, adult; *e*, one wing; *f*, a leg; *a–d*, natural size; *e*, *f*, enlarged. (Redrawn from Riley)

years it appeared on the Atlantic coast and has become a pest throughout the country wherever potatoes are grown.

The Cotton Boll Weevil. The cotton boll weevil (*Anthon'omus gran'dis*) is one of the small snout beetles, the larva of which lives in the buds of the plant, destroying the fibers so that the infected boll produces no cotton. The boll weevil is not a native of the United States, but came in over the Mexican boundary about 1890. It has spread widely over the cotton-growing states. In 1923 it destroyed more than one half of the entire cotton crop.

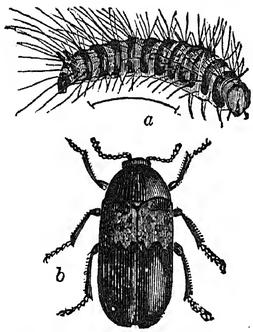


FIG. 36. One of the dermestids. (Enlarged)

a, larva; *b*, adult beetle. (Courtesy of the Illinois State Natural History Survey)

Buffalo Beetles. Households are frequently bothered by hairy, black or brown larvæ (Fig. 36, *a*) which voraciously devour clothing, carpets, upholstering, furs, and almost anything of animal origin. These are the larvæ of the buffalo beetles (*Anthre'nus*, Fig. 36). The work of these larvæ is often taken for that of moths. It is difficult to keep collections of bird and mammal skins and dried insect collections because of these destroyers. There are several genera (see page 107 for definition of *genus*), all of which belong to the one family called dermestids or "skin devourers."

Wood-Boring Beetles. Beetles known as the long-horned and the flat-headed beetles or buprestids do great damage

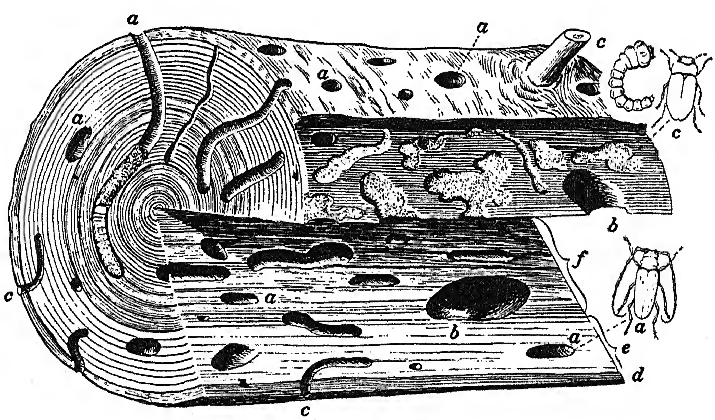


FIG. 37. The work of borers in wood. (Reduced)

a, long-horned borer and its tunnels; *b*, tunnel of another species of long-horned borer; *c*, flat-headed borer and its tunnels; *d*, bark; *e*, sapwood; *f*, heartwood. (Courtesy of the United States Department of Agriculture)

to trees. The larvæ dig tunnels and burrows in the bark and wood, frequently causing the death of trees and greatly injuring the wood for use as lumber (Fig. 37).

Definition of Coleoptera (Gr. *koleos*, "sheath"; *pteron*, "wing"). The insects which we have considered in this chapter agree in possessing biting mouth parts and hardened sheaths to cover the posterior wings. The wing covers, or elytra, meet in a straight line down the middle of the back. These insects are termed beetles or Coleop′tera. The Coleoptera undergo complete metamorphosis, — the life history comprising the egg, an active larva or grub, a resting pupal stage, and the winged adult.

CHAPTER VII

THE BUTTERFLIES AND MOTHS: LEPIDOPTERA

And what's a butterfly? At best
He's but a caterpillar drest.

JOHN GAY

The Monarch Butterfly. One of the commonest and best known of our butterflies is the monarch, or milkweed, butterfly (*Dan'aus archip'pus*; see illustration facing page 58). It is a tawny-colored species expanding about ten centimeters (four inches). The wings have black veins, and the margins are black with white spots. The colors are due to the presence of tiny scales, which cover the surface regularly and overlap like the shingles on a roof. Besides serving for the display of the colors, the scales also strengthen the wings. The scales are in origin modified hairs, like those which cover the rest of the body. The same mouth parts that were described for the grasshopper are present here also. They have become elongated and modified to form a tube which is coiled beneath the head when the butterfly is not feeding. This *proboscis* is formed from the lengthening and union of the maxillæ. The mandibles are so small as to be hardly visible. The anterior legs are so much reduced in size that they cannot be used for walking, and the butterfly is therefore practically four-legged. This is not true of all butterflies, for in many of them the front legs are well developed.

Practically all the butterflies living in the northern part of the United States spend the winter as inactive adults or as larvæ or pupæ. But the monarch butterfly is not present in the North in any stage during the winter. It

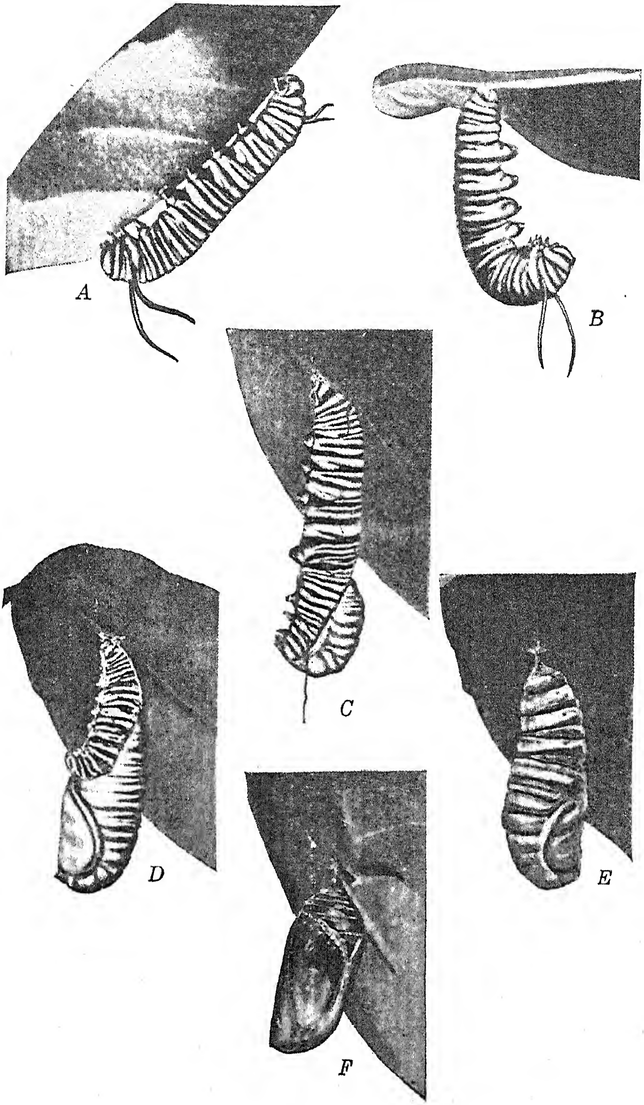


FIG. 38. Stages in pupation of the milkweed caterpillar.[1] (Slightly reduced)

[1] Reprinted by permission from *Entomology*, by J. W. Folsom, published by P. Blakiston's Son & Co.

passes the winter in the South, like our migratory birds, and with approaching warm weather the different individuals slowly work their way northward, the females laying eggs in different places in the course of the journey. The eggs are pale green and are deposited singly on the leaves of the different species of milkweed. In about four days the eggs hatch into caterpillars (Fig. 38), which immediately proceed to devour the eggshells. For the rest of their larval existence the caterpillars are voracious feeders on the leaves of the milkweed. They grow for two or three weeks, molting several times as they increase in size, till they are conspicuous objects, nearly five centimeters (two inches) long, prominently banded with yellow and black (Fig. 38). When through feeding, each larva spins a pad of silk on some convenient support and, molting once more, appears in a mummy-like pupal condition (Fig. 38), attached by hooks at its extremity to the pad of silk spun by the larva. In the inactive pupal stage the milkweed butterfly is bright green with golden spots. To this, and to some of the other naked pupæ of butterflies, the name *chrysalis* is given. The insect remains in the pupal stage for ten or twelve days, when the skin splits (Fig. 39) and the butterfly comes out with crumpled wings, which soon expand and harden.

The monarch butterfly possesses remarkable powers of flight. Mr. Scudder, in his *Guide to Butterflies*, states that it has been seen at sea five hundred miles from land, and that it has within thirty years spread over nearly all the islands of the Pacific, and even to Australia and Java.

It is asserted that these butterflies, although so brilliantly colored and conspicuous, are not fed upon generally by birds and other animals which might use them for food, owing to their possessing a strong odor which renders them distasteful. If this is the case, the distinctive coloration

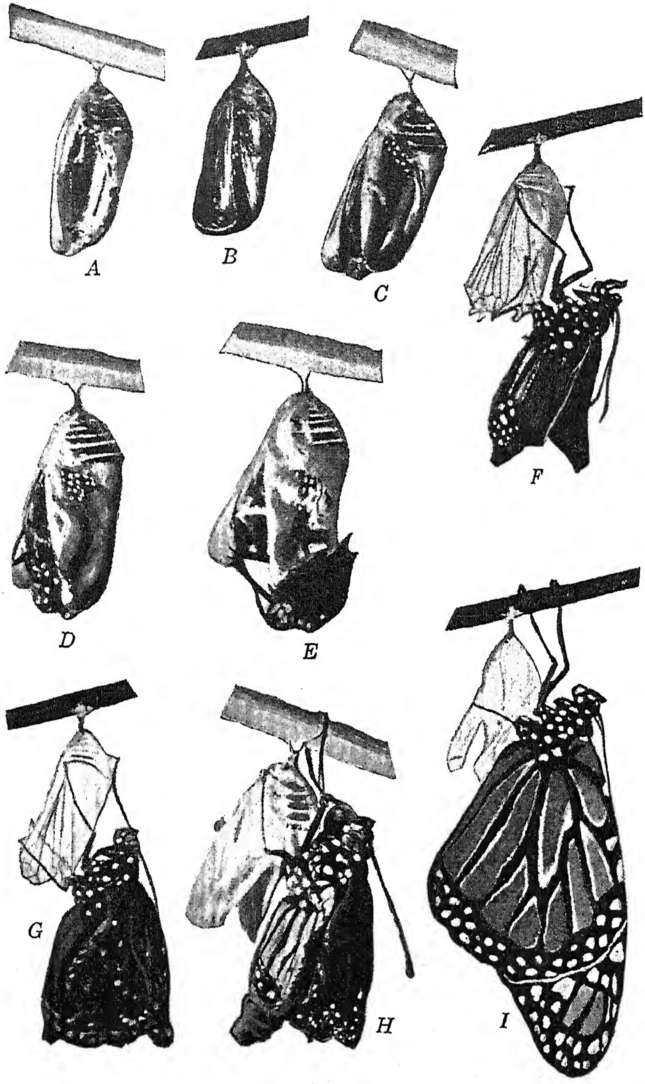


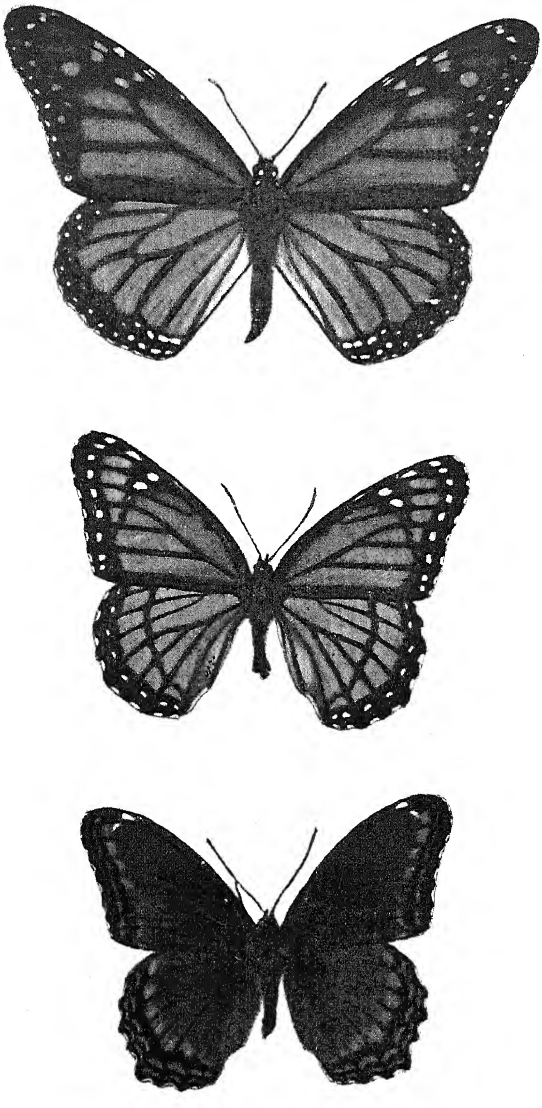
FIG. 39. Emergence of the milkweed butterfly from its chrysalis.[1] (Slightly reduced)

[1] Reprinted by permission from *Entomology*, by J. W. Folsom, published by P. Blakiston's Son & Co.

may be an advantage rather than otherwise, making it easy for any animal to distinguish them from edible species. The brilliant colors are usually cited as an illustration of *warning coloration.*

The Viceroy Butterfly. Another butterfly of an entirely different genus (see page 107) and without any offensive odor, — the viceroy (*Basilar'chia archip'pus*; see illustration facing this page), — closely resembles the monarch. The viceroy belongs to a group of butterflies whose general body coloration is blue and white, but instead of the livery of its relatives it wears that of the monarch. It offers the best-known illustration in North America of what is called *protective mimicry*, a term applied to those cases in the animal kingdom in which a group of animals without disagreeable qualities resembles, to a greater or less extent, animals provided with special means of defense. Protective mimicry will be seen to differ from warning coloration in that the latter is believed to protect an animal by marking it as a source of real danger or unpleasantness; the former is believed to protect by suggesting characters which have no existence in fact. This explanation of the color of the viceroy has been called in question, and observations are wanting to show that the birds of the eastern United States feed generally upon butterflies. Many cases of protective mimicry are known among the butterflies of Africa and South America. By the use of the term it is not meant, of course, that there is anything conscious in the mimicry.

Swallowtail Butterflies. The magnificent insects called swallowtail butterflies, widely distributed over the world, have received their common name on account of the shape of the hind wings. They often exhibit, within the limits of a single species, great variation in color, size, and even in the shape of the wings. The variation in form, size, and color between individuals of the same species is spoken of as



MIMICRY

The monarch butterfly, the viceroy, and a close relative of the viceroy. The lowermost figure shows typical coloration of the members of the genus to which the viceroy belongs. (Courtesy of Boston Society of Natural History)

because its larvæ (Fig. 40, *c*) live on the cabbage plant. The tips of its anterior wings (Fig. 40, *a*) are grayish. The male has one spot of gray on each of the anterior wings, the female two. There is also a gray spot on the anterior margin of the posterior wings of both sexes. There are several variations of this species; one form has both sexes entirely white. This butterfly is another insect pest which has come to us from a foreign country, and which has been most prosperous in its adopted home. It first appeared in the region of Quebec about the time of the Civil War. Within twenty-five years it spread from the Atlantic to the Pacific, and from northern Canada to the Gulf of Mexico. In the far north it has two broods and in the south many broods each year. By appearing earlier in the season and having more than one brood a year it has driven out of our gardens the native cabbage butterflies. These are rarely found now except living on the wild relatives of the cabbage.

The larva of the cabbage butterfly is the familiar green cabbage worm, which eats its way well into the head of cabbage. The native cabbage butterflies (*Pi′eris na′pi*) which this imported form has so largely replaced were much less destructive, as their larvæ feed only on the outer cabbage leaves.

One of the better-known native species is called the checkered white (*Pi′eris protod′ice*), so named because of the beautiful, checkered dark and white pattern on the wings of the female. The wings of the male are spotted.

Economic Importance of Butterflies. In contrast with the moths, which are to be discussed later, the butterflies are practically wanting in destructive habits. The cabbage butterfly is the only one of really great economic importance. It seems especially fitting that these creatures, which add so much of beauty to man's surroundings, should not be his enemies.

Skippers. The skippers (*Epargy'reus tit'yrus*, Fig. 41) are, like the butterflies, diurnal insects and are found in fields and along woodsides, where they dart about in a most erratic manner. They are closely allied to the butterflies. The butterflies (Fig. 40, and illustration facing page 58) have club-

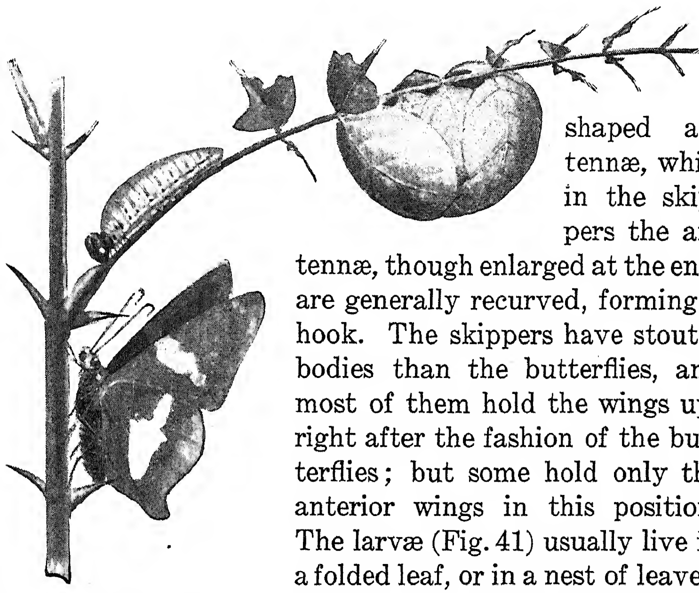


FIG. 41. Metamorphosis of skipper. (Natural size)

shaped antennæ, while in the skippers the antennæ, though enlarged at the end, are generally recurved, forming a hook. The skippers have stouter bodies than the butterflies, and most of them hold the wings upright after the fashion of the butterflies; but some hold only the anterior wings in this position. The larvæ (Fig. 41) usually live in a folded leaf, or in a nest of leaves, and pass the pupal stage in a thin cocoon of silk spun by the caterpillars before changing. In this latter respect, too, the skippers differ from the butterflies, since the latter (as shown in Figs. 38, 39) have a naked pupal stage.

Commercial Silkworm Moths. Allied to both butterflies and skippers is the great group of moths, — stout-bodied insects, the antennæ of which are usually feather-like or thread-like (Figs. 42, 43). Moths have the habit of holding the wings horizontally when at rest. They are nocturnal or

diurnal in their habits, though by far the larger number fly by night. Most of them spin some kind of cocoon in which they pass the pupal stage.

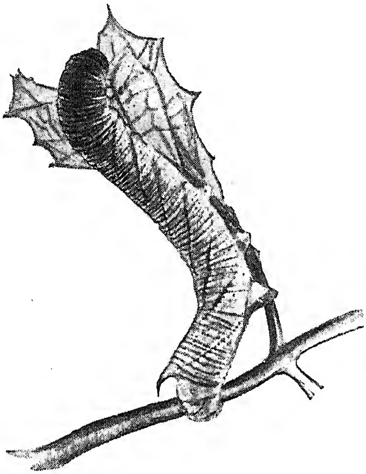
We shall first consider the silkworm moths. Of these the best known, as it is economically the most important, is the Chinese silkworm moth (*Bom'byx mo'ri*). Cultivated in China from very early times, the Chinese jealously guarded the secrets of the manufacture of silk. As the story goes, in the middle of the sixth century two monks brought the eggs to Constantinople by stealth, concealed in a hollow bamboo cane. The cultivation of the silkworm then spread rapidly to those parts of Europe suited to its culture. From 1609 to the present day various efforts have been made to introduce silk culture into the United States, the plan of bounties and rewards to stimulate its growth having been tried by the rulers in colonial days, and by several states since the war of 1861–1865. These artificial means have so far not met with great success. In China the caterpillar thrives best on the leaves of the white mulberry, but it has been found to do well on the Osage orange.

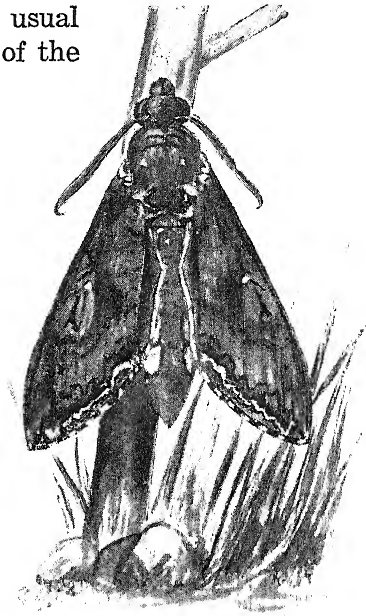
The silk glands extend through the body of the caterpillar and open into the mouth. Toward the time of pupation they increase in size and produce about four thousand yards of material, which, on being exposed to the air, hardens and becomes the silk of commerce. As there are two sets of these glands, each silk filament is really double. Within this cocoon of silk the larva casts its caterpillar skin and becomes a pupa. In silk culture the cocoons are placed in an oven to kill the pupæ, and the silk is softened by being placed in warm water. Then, by means of a twig moved about among the cocoons, loose ends of several of them are caught, united into one thread, and wound on a reel, which is placed at a distance from the hot water so that the silk may dry. This is the raw silk of commerce.

Giant Silkworm Moths. We have several large moths in the United States, expanding from ten to fifteen centimeters (four to six inches), whose larvæ spin silken cocoons, some of which have been utilized to a limited extent by man. They are magnificent insects, with broad wings beautifully colored, and with large feather-like antennæ. The antennæ of the male are much larger than those of the female. Even in crowded cities the gorgeous brown and red *cecropia* is not uncommon, while the *polyphemus*, *luna*, and *promethea* are species of especial delight to those who love the beautiful. The larvæ feed on the leaves of forest and fruit trees and are more or less armed with a variety of colored spines and tubercles. The caterpillars, like other larvæ which feed upon plant food, are remarkable for the amount of food which they consume and the great increase in size in early life. The caterpillar of the American silkworm moth (*Te'lea polyphe'mus*), which weighs on hatching one twentieth of a grain, increases to ten times its weight within ten days, and to over four thousand times its weight in fifty days. By this time it has consumed over one hundred oak leaves, weighing almost three quarters of a pound, and drunk nearly one half an ounce of water. The larvæ of these moths spin conspicuous brown cocoons, which can easily be collected in the winter from the branches and leaves of trees to which they are attached. In the spring the imagoes escape from one end of the cocoons by cutting the silk with a pair of stout spines, one on each side of the thorax, at the base of the anterior wings.

Underwings. A very striking group of moths is the underwings (*Catoc'ala*), which have the anterior wings in sober tints of brown or gray, but the posterior wings black with broad markings of red or yellow. When at rest the posterior wings are covered, and the moth tends to be protectively colored; but when in flight the broad, contrasting

colors are conspicuous. It is usual to account for the coloration of the





anterior wings by the principle of protective resemblance.

Hawk Moths. The hawk moths or sphinx moths (Fig. 42) are easily recognized by the stout conical body, long coiled proboscis, narrow pointed wings, and the slender antennæ. They are dressed, for the most part, in quiet olive and brown tints and fly chiefly at twilight. Their larvæ are large naked caterpillars, often with a curved horn near the posterior extremity. The

FIG. 42. A sphinx moth. (Slightly less than natural size)

Adult, larva, and pupa

tobacco worm and tomato worm are the larvæ of a well-known species, *Protopar'ce sex'ta* (Fig. 42), found on tomato,

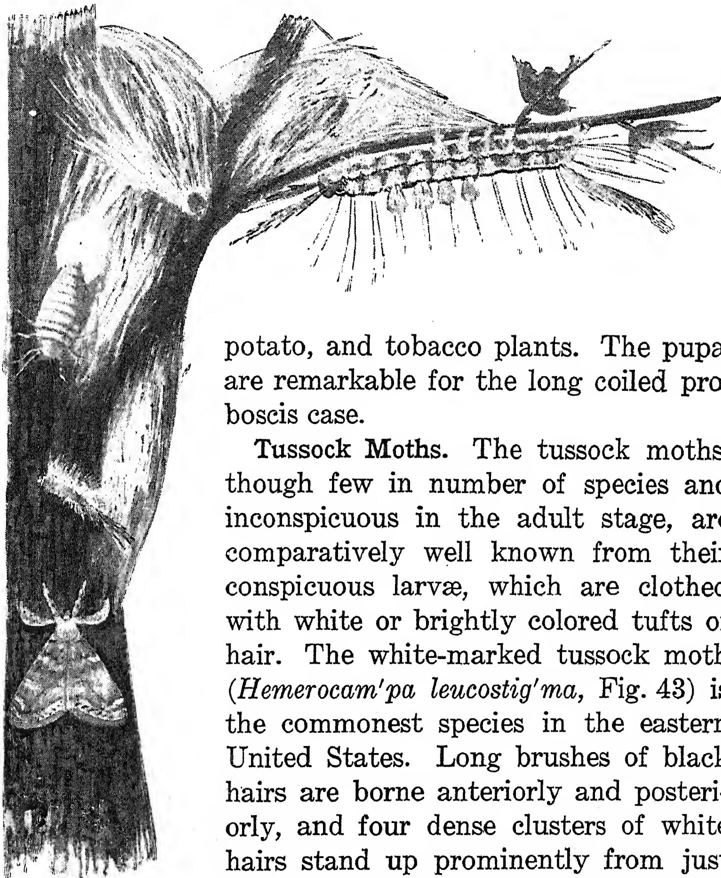


FIG. 43. Metamorphosis of tussock moth. (Natural size)

potato, and tobacco plants. The pupæ are remarkable for the long coiled proboscis case.

Tussock Moths. The tussock moths, though few in number of species and inconspicuous in the adult stage, are comparatively well known from their conspicuous larvæ, which are clothed with white or brightly colored tufts of hair. The white-marked tussock moth (*Hemerocam'pa leucostig'ma,* Fig. 43) is the commonest species in the eastern United States. Long brushes of black hairs are borne anteriorly and posteriorly, and four dense clusters of white hairs stand up prominently from just behind the head. The females are wingless and look more like white grubs than moths. When they emerge from the cocoons the eggs are laid close by, often on the cocoons. Fig. 43 shows the female in the act of laying eggs in such a situation.

The Gypsy Moth. The dangers of introducing destructive insects from another country are well shown in the case of the gypsy moth (*Porthet'ria dis'par*). About 1868 an entomologist in Massachusetts set free some specimens of this moth. His act has caused the direct expenditure of millions of dollars and the loss of many forest and shade trees. Though the female rarely flies the species has become widely distributed throughout the New England states. The larvæ when abundant completely strip all the leaves from the trees.

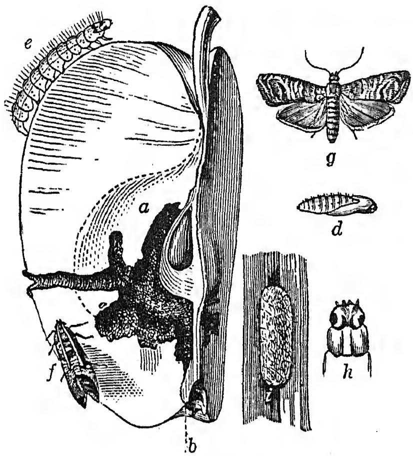


FIG. 44. Stages in the life of the codling moth. (Natural size)

a, tunnel of larva in apple; *b*, point where larva entered the apple; *d*, pupa; *e*, fully grown larva; *f* and *g*, adult moths; *h*, head end of larva; *i*, pupa in cocoon. (After the Illinois State Natural History Survey)

The Codling Moth. There are several insect larvæ which live in apples, all of which are commonly called apple worms. The most important one of these is the larva of the codling moth (*Carpocap'sa pomonel'la*). It has become so widely spread and so abundant in this country that marketable apples can be produced only by following a carefully timed program of spraying. The larvæ are killed by eating the poison when they attempt to eat their way into the young apples. The adult moths (Fig. 44, *f*, *g*) become mature about the time that apples are in bloom. The eggs are laid upon the blossoms. As soon as the larvæ (Fig. 44, *e*) are hatched they begin to eat their way into the blossom

end (Fig. 44, *b*) of the young apples. If a poison spray has been applied at the proper time the young larva gets a dose of poison with its first and last meal and the apple escapes being classed as a wormy cull.

Clothes Moths. Some of the small brownish "moth millers" so commonly seen flying in houses are the adults of the clothes moth (Fig. 45), often so destructive of clothing, carpets, and upholstered furniture. The adult moth lays its eggs on woolen material. When the eggs hatch, the larvæ proceed to eat the cloth. There are three species of clothes moths, each belonging to a different genus.

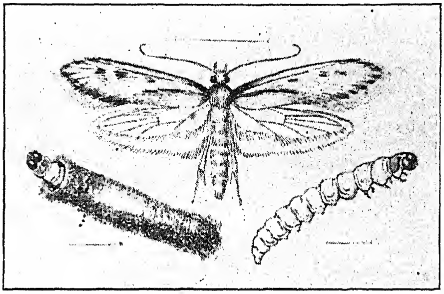


FIG. 45. A clothes moth. (Enlarged)
Adult, larva in case, and larva. (Courtesy of the United States Department of Agriculture)

The Corn Borer. The European corn borer is the larva of a moth which causes great damage by boring into the stalks of corn. This species (*Pyraus'ta nubial'is*) was very recently introduced into this country, but it is making alarming progress in its invasion of the corn belt. Individual states and the federal government have appropriated very large sums of money for the study of this insect, but so far there seems to be small hope of checking its spread.

An insect which feeds on the surface of a plant may be attacked directly by poison food or by deadly sprays. But when an insect does its damage inside of the tissues of a plant there is little chance of reaching it.

Measuring Worms. The measuring worms (Fig. 46) are the larvæ of a group of medium-sized moths. When some of these larvæ are at rest, it is difficult to believe them to

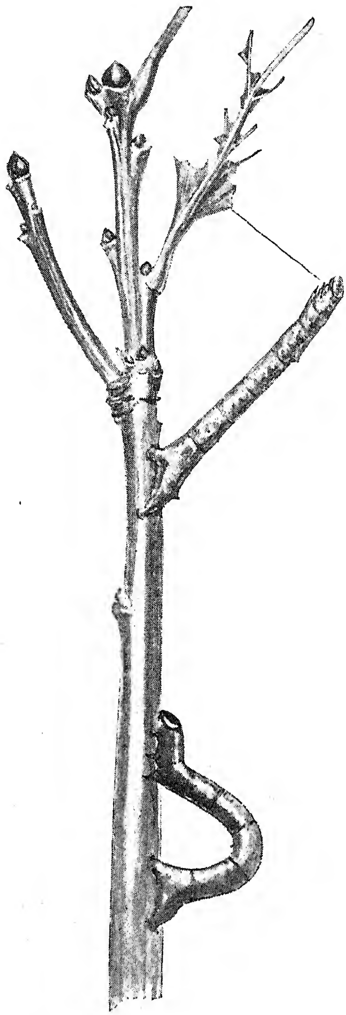


FIG. 46. Measuring worms. (Natural size)

be caterpillars. Most of them have three pairs of legs less than other caterpillars, so that a looping gait is the result, whence the name "measuring worms." They have the habit, when disturbed, of dropping to the ground on a silken thread, which they spin as they fall.

Definition of Lepidoptera (Gr. *lepis* (*lepidos*), "scale"; *pteron,* "wing"). The butterflies, skippers, and moths, collectively, are spoken of as Lepidop′tera. The Lepidoptera have four large wings covered with scales, sucking mouth parts, and undergo a complete metamorphosis. The larvæ, called caterpillars, with few exceptions, feed upon the leaves of plants.

The butterflies and skippers are active by day, and the moths fly at night or in the twilight. Most moths have stout bodies and feather-like antennæ. Skippers have antennæ usually ending in an enlarged hook-like tip. Butterflies have enlarged knobs at the tips of the antennæ. When at rest, butterflies usually hold their wings erect, and moths more commonly fold them against the body.

CHAPTER VIII

THE FLIES: DIPTERA

. . . like small gnats and flies as thick as mist
On evening marshes.

SHELLEY

House Flies. The common house fly (*Mus'ca domes'tica,* Fig. 47) is a cosmopolitan insect. The eyes are very large, occupying the whole side of the head; the antennæ are short and composed of only three joints, the third bearing a bristle. The mouth parts are formed for sucking and lapping. They consist of a short tongue-like proboscis, with large oval flaps, or lobes, on each side. These flaps are extensile and are roughened like a file on the inner surface, thus permitting of their use as a scraper, by means of which the insect can lap up sweets or other food. The proboscis is made up of the united maxillæ. The thorax bears but one pair of wings, though the rudiments of others, called balancers or *halteres,* can be seen in the form of two little round objects, borne on slender stalks. These balancers also act as organs of hearing. Two broad scales are found on the sides of the thorax, just behind the wings. The legs are fitted for running. The pulvilli are large and bear tubular hairs, which secrete a sticky fluid, by means of which the fly can walk on smooth surfaces, even when upside down.

The eggs, over one hundred in number, are laid usually in horse manure or garbage. They hatch within a day into smooth, white, almost transparent, conical, footless larvæ, called maggots. The rudimentary mouth parts consist only of

a few small hooks. The larvæ feed for about a week, growing rapidly and molting twice within that time, and then pass into an inactive pupal stage within the larval skin. In a week more the perfect insect appears by making a circular hole in one end of the pupal case by means of a large bladder-like bulb, which swells out on the forehead and is later withdrawn into the head. Thus within about two weeks the life history is completed. As the imagoes soon lay eggs, there may be several generations in the course of the summer. With the approach of cold weather most of the flies die, although some hibernate in sheltered places.

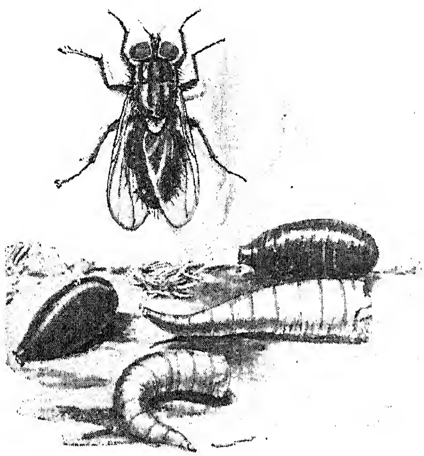


FIG. 47. Metamorphosis of house fly. (Enlarged)

Someone has made the calculation that if all the offspring of a single pair of flies starting to reproduce in April were to live, by August there would be from this one original pair enough to cover the entire earth with a layer of flies forty-seven feet deep.

The house fly has always been considered a nuisance about the house; but a more serious charge is laid at its door, — that of transporting on the pulvilli and proboscis the germs of typhoid fever. With the knowledge of its favorite breeding place it should be possible, by insisting on cleanliness in stables, by the daily collection of manure and garbage and their proper disposal, to mitigate greatly, if not entirely destroy, this menace to health.

Flesh Flies. Equally well known are the blowfly (*Calliph'ora vomito'ria*) and the bluebottle (*Lucil'ia cæ'sar*), which deposit their eggs on fresh and decaying meat. These flies hatch within a day, and the larvæ greedily devour the decaying material, not hesitating, when that task is finished, to devour each other.

The history of South Africa has been very largely controlled by the biting flies known as the tsetse flies of the genus *Glossi'na*. There are several species of these flies. By their bite they infect man and domestic animals with minute disease-producing protozoa known as trypanosomes. African sleeping sickness, one of the most deadly human diseases known, is produced by the bite of the tsetse fly. In large parts of South Africa practically all horses and cows are killed off by a disease known as nagana. Like human sleeping sickness this also is produced by trypanosomes, carried by the tsetse flies. The native game animals have recently been found to harbor the protozoa without suffering any apparent ill effects.

Botflies. The botflies are parasites in the larval stage; that is, they live in the bodies of other animals. There are nearly one hundred species known, infesting various animals, living either under the skin, in the nostrils, or in the stomach. The botfly of the horse (*Gastroph'ilus e'qui*, Fig. 48) attaches its eggs singly by means of a sticky substance to the hairs of the legs, where the larva is pretty sure to be swallowed when the animal licks or bites its legs to remove the irritation. The larva then attaches itself to the lining of the stomach by means of hooks which encircle its mouth, and for nearly a year feeds on the substance of the stomach wall. The pupal stage is passed in the earth, which is reached through the alimentary canal. A few of these parasites do no particular harm, but a large number may cause death.

The sheep botfly (*Œs'trus o'vis*) in a similar manner attacks the nostrils of sheep. The appearance of one of these flies in a flock of sheep is sufficient to throw them into a state of panic; they run about with their noses between their legs, or try to bury them in dust, to escape their tormentor. The female of this botfly does not lay her eggs as do most other insects, but retains them within her body till

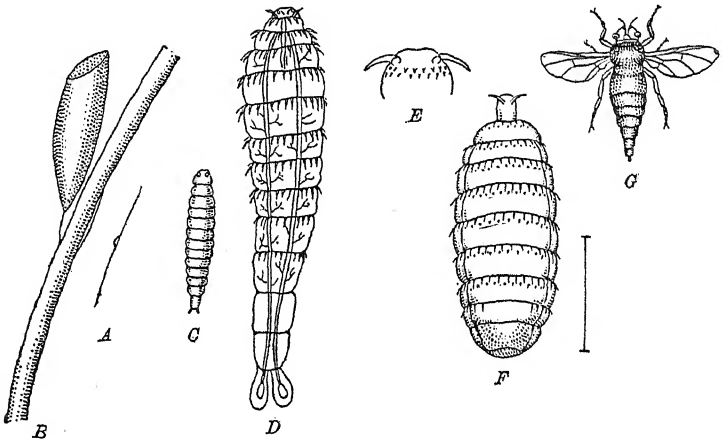


FIG. 48. Metamorphosis of horse botfly

A, egg on hair of horse (natural size); *B*, egg on hair of horse (enlarged); *C*, young larva (enlarged); *D*, young larva (much enlarged); *E*, spines; *F*, full-grown larva (twice natural size); *G*, female (natural size). (After Osborn, *Bulletin No. 5*, N.S., United States Department of Agriculture, Division of Entomology)

they hatch, and then deposits the living young, — that is to say, in her method of reproduction she is viviparous.

Fruit Flies. The minute flies (*Drosoph'ila*) so often seen about over-ripe fruit are commonly called fruit flies, pomace flies, or vinegar gnats. Much that we now know of the laws of heredity has come from the study of these minute flies. They are easily reared and reproduce so rapidly that they are favorite objects for laboratory study of the manner in which characteristics are passed from one generation to another.

Hover Flies. Often a collector captures an insect flying about flowers which has the characteristic manner and yellow and black colors of a wasp, but which has only two wings. It is one of the hover flies, many of which afford illustrations of protective mimicry. Some species of *Eris'talis* (Fig. 57) mimic the male honeybee and are therefore named drone flies; others belonging to *Volucel'la* (Fig. 57) mimic bumblebees. The larvæ of some feed chiefly upon aphids and are therefore beneficial to the farmer; yet others inhabit pools of stagnant water or decaying wood.

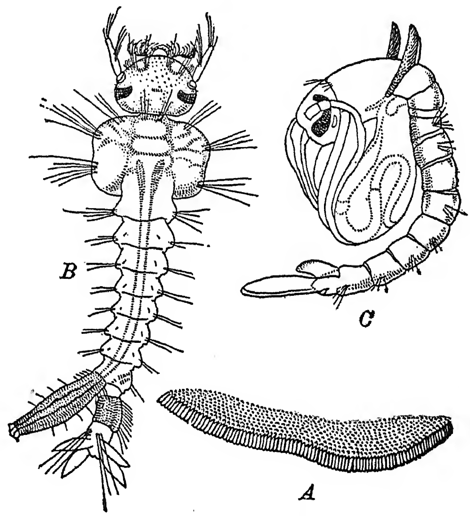


FIG. 49. Development of mosquito. (Enlarged)

A, egg mass; *B*, larva; *C*, pupa. (After Howard, *Bulletin No. 25*, N.S., United States Department of Agriculture, Division of Entomology)

Mosquitoes. The mosquitoes comprise a group widely distributed over the tropical and temperate regions of both hemispheres. In nearly all the species observed the mouth parts of the females only are fitted for piercing the skin of animals. The males, if they feed at all, probably suck the fluids of plants; in fact, both sexes in the past history of the race were probably, and are still, to some extent, plant feeders.

A common mosquito of the Mississippi Valley and the East is *Cu'lex pip'iens.* The female lays her eggs (Fig. 49) in irregular masses containing over two hundred eggs, on

the surface of the water early in the morning. Within a day they hatch, and the larvæ are the familiar, active creatures known as "wrigglers." The next to the last somite bears a long respiratory tube through which the larva breathes air when at the surface; the last somite is provided with four flaps (tracheal gills) which act as organs of respiration when the larva is beneath the surface. In addition to these methods of obtaining air, the skin is capable of absorbing oxygen, and a network of tracheæ lines the posterior part of the alimentary canal, so that oxygen may be obtained from the water taken in at the anal opening. The larvæ feed on small particles of decaying matter in the water, thus being useful as scavengers. After several molts and a life of about a week, if the weather is warm they then pass into the pupal stage, breathing by means of two air tubes arising from the thorax. In about two days the pupal skin splits down the back and the imago works itself out of its old skin, dries its wings, and flies away. Cold weather retards these changes considerably.

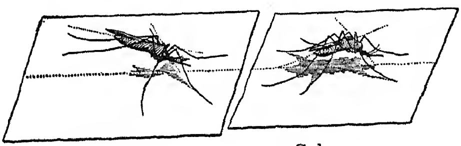


FIG. 50. Resting positions of mosquitoes. (Slightly enlarged)
After Grassi

Great interest attaches to the mosquitoes by reason of the fact that malaria and yellow fever are both wholly dependent upon mosquitoes for transmission from one person to another. Malaria is carried by mosquitoes belonging to the genus *Anoph'eles*, the females of which may be distinguished from the females of *Culex* by the greater length of the palpi. *Anopheles* shows a tendency, especially on horizontal surfaces, to alight with the hind end of the body raised at a considerable angle to the surface; *Culex* holds

the body parallel to the surface. In *Anopheles* the body and beak are in the same plane no matter what the position is; *Culex* is humpbacked, with the beak pointing downward. These various distinctions are well shown in Fig. 50. The males of both genera can be distinguished from the females by their larger and more feathery antennæ.

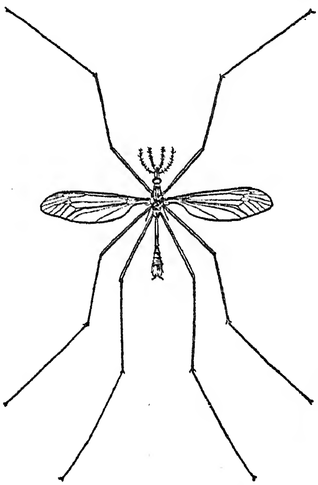


FIG. 51. Crane fly. (Enlarged)

From the Illinois State Natural History Survey

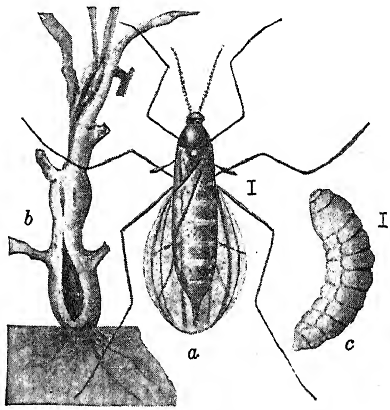


FIG. 52. The Hessian fly

a, adult; *b*, wheat plant suffering from attack of the fly; *c*, larva. The small lines to the right of *a* and *c* indicate natural length. (After Berlese)[1]

Many localities can be practically rid of these pests by the drainage of the swamps or ponds in which they breed; by the use of kerosene or other oils on the surface of such waters; or by the introduction of fish that feed on the larvæ.

Minnows, goldfishes, sunfishes, and sticklebacks are all mosquito destroyers. It must be remembered that the insect will breed successfully in any transient pool of water, or in

[1] Reprinted by permission from *Applied Entomology*, by H. T. Fernald, published by the McGraw-Hill Book Company, Inc.

any receptacle where water is left standing long enough for the eggs to develop into mature mosquitoes.

Crane Flies. The crane flies (Fig. 51) look so much like mosquitoes that many people mistake them for an extremely large race of bloodthirsty mosquitoes. In fact, they are unable to bite.

The Hessian Fly. The Hessian fly (*Phytoph'aga destruc'tor*) is a small gnat-like fly (Fig. 52) which appeared in this country soon after the Revolution. It is thought that it was brought over from Europe in straw transported by the Hessian soldiers. The young (Fig. 52, *c*) develop in the stems of wheat, rye, and barley. Here they do so much damage that it is estimated that more than 10 per cent of the wheat crop is destroyed by this fly in an ordinary year.

Definition of Diptera (Gr. *dipteros*, "two-winged"). The insects collectively called flies agree in the possession of two wings, the place of the posterior pair being taken by the halteres, or balancers, which may therefore be considered reduced wings. Although a few other insects have but a single pair of wings, the flies alone possess halteres. The flies belong to the order Dip'tera. The Diptera have the mouth parts fitted for sucking or piercing. They undergo complete metamorphosis. The larvæ are commonly known as maggots.

CHAPTER IX

THE ANTS, BEES, AND WASPS: HYMENOPTERA

For so work the honey-bees,
Creatures that by a rule in nature teach
The art of order to a peopled kingdom.
SHAKESPEARE, King Henry V

Social Wasps. The common brown wasps (*Polis'tes*, Fig. 53) are interesting on account of their communal life in nests of paper made from wood pulp. The mouth parts are fitted both for biting hard substances and also for lapping the fluids of plants. The mandibles are much the same as in such biting insects as the grasshoppers; the maxillæ are elongate, sharp-pointed, lance-like organs, and the labium is a flexible, tongue-like structure covered with hairs, to which sweets adhere. There are four membranous, transparent wings, with few veins. The female is provided with a formidable sting, — an important means of defense, — which is in origin a modified ovipositor.

Early in the spring a female *Polistes*, which has wintered in a crevice, begins the construction of a nest in some suitable place, either on the under side of a roof, especially in deserted houses or barns, or on the ground beneath a stone. If there are fences or barns in the region, she will very likely obtain a supply of wood from them; if not, from stumps and dead trees. After being chewed by her and moistened by a secretion from her mouth, this material is fashioned by the feet and mandibles into circular cells. These become hexagonal as their number is added to and the pressure increases. The whole is waterproofed by a glutinous secre-

tion, which is said to be increased in amount in those cells which are most exposed to the weather. As soon as one cell is finished the female lays an egg in it, and to her duty of enlarging and strengthening the nest she soon has to add the care of the footless, worm-like larvæ, which hatch in a few days. These are fed with both plant and animal food, the former consisting of nectar which has been swallowed and later regurgitated (that is, thrown back after being

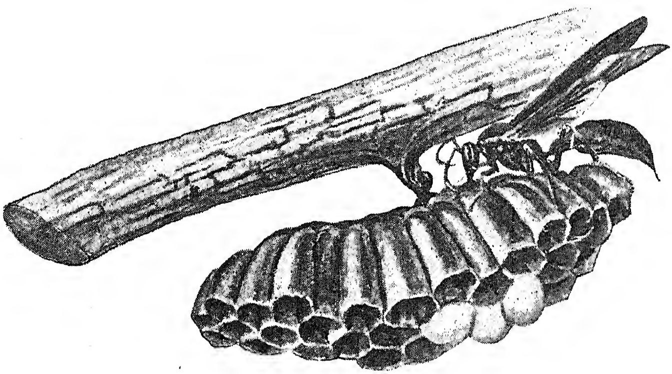


FIG. 53. Paper-making wasp and nest. (Natural size)

swallowed); the latter, of caterpillar meat chopped fine by the mandibles and worked into a jelly-like mass. In about three weeks' time the first-born larvæ spin a silken lining and covering to the cell and pass into an inactive pupal stage. Three weeks later the first imagoes appear, after having cut a circular opening in the end of the cell.

These first imagoes differ somewhat from their mother and are really imperfectly developed females, called neuters or workers. They have the power, under certain conditions, of laying eggs, but their eggs never produce true females. Generally the workers attend strictly to the business of caring for the young and repairing and enlarging the nest. They assume care of the young at about the third day.

From the time the workers take up the tasks of the nest the female is left free to devote all her energies to laying eggs, and the nest is rapidly made larger by the workers. Toward September males and females appear from the cells, which up to this time have produced only workers. The males die soon after mating. On the approach of cold weather, the workers also die, and only females remain to hibernate and begin a new nest the next spring.

Another type of nest, in which the horizontal layers are inclosed in a thin envelope, is made by the somewhat larger and stouter-bodied wasps (*Ves'pa*, Fig. 57) commonly known as hornets. These wasps are generally conspicuously marked with yellow, and their nests may be a foot and a half in diameter.

The social wasps are the original paper-makers of the world. The first suggestion as to the manufacture of paper by man may have come from watching the work of these insects, though the necessary steps may well have been taken without such suggestion, as the use of the leaves of palms and the bark of several trees is still common in China and India. It is interesting to note that though the wasps were the original inventors of paper, they have, in some cases, learned to take advantage of man's present greater facilities for its manufacture, thus saving themselves the trouble of preparing the raw materials.

Solitary Wasps. Those wasps which are solitary in habit make nests in various situations and of different materials and store them with food, generally insects and spiders. These they often sting so as to paralyze but not to kill them. Each species has its own method of providing food, and each keeps pretty closely to the same material for nest-building. Thus the common mud dauber (*Scel'iphron*, Fig. 54), seen flying about on sunny days over the muddy edges of puddles and pools, builds its nests of clay and pro-

visions them with spiders. Each cell is filled with paralyzed spiders; on top, one egg is laid and the cell is sealed. When the larva hatches, it finds the requisite amount of food to

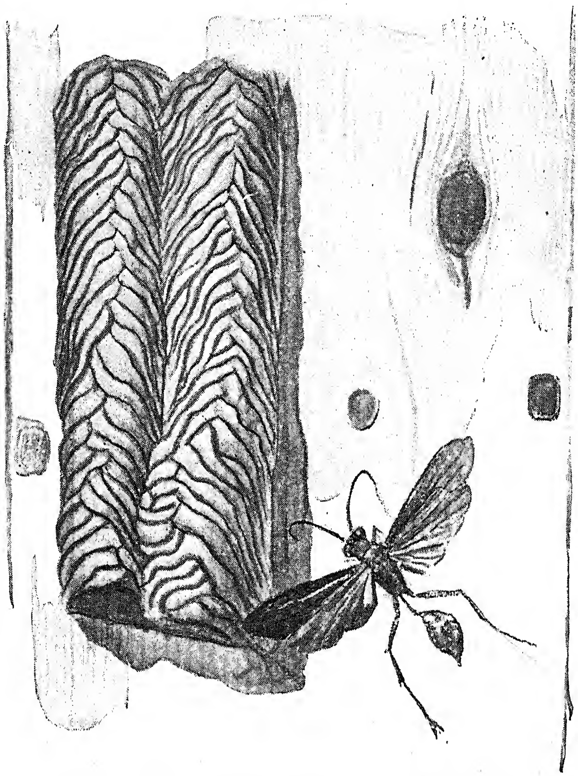


FIG. 54. Mud dauber and nest. (Natural size)

carry it to the pupal stage. These wasps are distinguished by the long pedicel, or stalk, joining the thorax to the abdomen.

The digger wasps of the West, which belong to the genus *Sphex* (Fig. 55), make holes a little over a centimeter (about half an inch) in diameter and two or three centimeters deep,

in the hard, sun-baked earth, often choosing a place beneath the protection of the leaf of some plant. These holes they provision with caterpillars, which they sting in several places till they are paralyzed. In the process of provisioning the nest some species close the opening with a pellet of earth or with small stones, which they remove when they

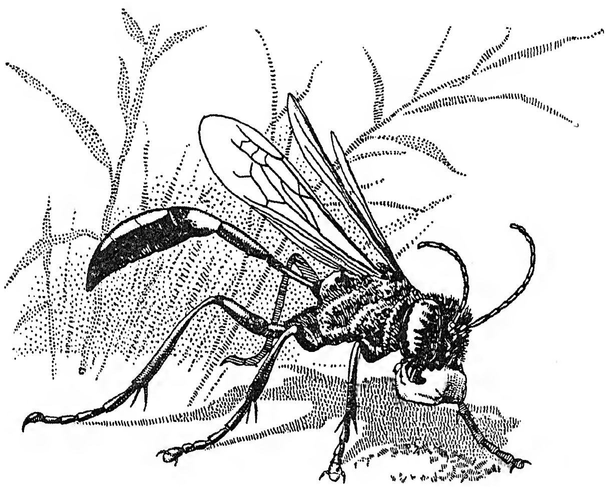


FIG. 55. Digger wasp using pebble. (Enlarged)[1]

return with a new caterpillar. Dr. and Mrs. Peckham, who have studied these insects very carefully, say that this is, however, not an invariable habit, some individuals leaving the nest open while searching for more caterpillars. These authors have this to say of the habits of one of these insects:

Just here must be told the story of one little wasp whose individuality stands out in our minds more distinctly than that of any of the others. We remember her as the most fastidious and perfect little worker of the whole season, so nice was she in her adaptation of means to ends, so busy and contented in her labor

[1] From Peckham's *Solitary Wasps*.

of love, and so pretty in her pride over her completed work. In filling up her nest she put her head down into it and bit away the loose earth from the sides, letting it fall to the bottom of the burrow, and then, after a quantity had accumulated, jammed it down with her head. Earth was then brought from the outside and pressed in, and then more was bitten from the sides. When, at last, the filling was level with the ground, she brought a quantity of fine grains of dirt to the spot, and, picking up a small pebble in her mandibles, used it as a hammer in pounding them down with rapid strokes, thus making this spot as hard and firm as the surrounding surface. Before we could recover from our astonishment at this performance she dropped her stone and was bringing more earth. We then threw ourselves down on the ground, that not a motion might be lost, and in a moment we saw her pick up the pebble and again pound the earth into place with it, hammering now here and now there, until all was level. Once more the whole process was repeated, and then the little creature, all unconscious of the commotion that she had aroused in our minds, unconscious, indeed, of our very existence, and intent only on doing her work and doing it well, gave one final comprehensive glance around and flew away.

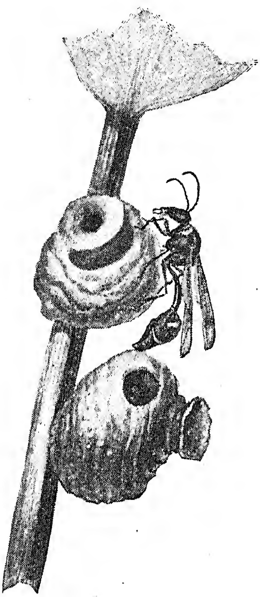


FIG. 56. Potter wasp and nests. (Natural size)

A common North American species of solitary wasp is called the potter wasp (*Eu'menes frater'na*, Fig. 56). It builds a pretty little jug-shaped nest of clay or mud, which it attaches to vegetation and provisions with caterpillars. The young, when full-grown, escapes through a hole which it cuts in the side of the nest, as shown in the lower of the two nests drawn in Fig. 56.

The Honeybee. The life history of the honeybee (*A'pis mellif'ica,* Fig. 57) has been quite well understood for a long time. This insect offers a most interesting illustration of a society all the members of which act together for the good of the community. In their community, specialization of work has been developed to a remarkable extent. The honeybee, originally a native of the Eastern Hemisphere, possibly from the region along the eastern shore of the Mediterranean Sea, has been domesticated from very early times for the sake of its two important products, honey and wax. Escaped swarms in this country have become the wild honeybees, which nest in hollow trees. In early summer a bee community in good condition may contain from twenty-five to thirty-five thousand workers, several hundred males, called drones, but only one female, called the queen bee. The queen bee may be distinguished from the workers and drones by her larger size. The drones are stouter than the workers and have no sting.

Upon the workers devolves most of the labor in connection with the life of the community. They secrete the wax and fashion it into the cells of which the home is composed. They bring water to the hive. They collect nectar from flowers and later regurgitate it and ripen it into honey; they bring pollen to mix with nectar to make "beebread;" they gather propolis, a gummy substance from bud scales of certain trees, especially the poplar, for filling crevices and covering foreign objects which are too big to be removed from the nest. When the young are hatched the workers act as nurses and housekeepers for the community, feeding the young and keeping the hive free from all substances which might decay. In warm weather some of them may be seen at the entrance and along the passageway, keeping the air in motion with their wings, thus setting up a current which provides air and helps ripen the honey by evaporating the water

in it. Finally, as everyone knows, they are the defenders of the hive, and by their great numbers and formidable stings they constitute a bodyguard of no mean pretensions.

The name "queen bee" is misleading, if it suggests any control or management of the affairs of the hive. She is carefully guarded by the workers, but that is on account of her importance to them as the only fertile female in the community, though they can, as we shall see, produce other queens from eggs which were destined for workers, if necessity arises. As far as having any power to rule is concerned, she is, in reality, ruled by the workers. It is her function to lay the eggs from which all the other members develop. Those eggs destined to become workers are laid in cells of ordinary size; those which are to become males are placed in slightly larger cells; and those which are to become queens, though differing in no way at first from those which produce workers, are placed in special "royal" cells, much larger and of an irregular shape. They are, of course, few in number compared with the others.

When the eggs hatch, all the larvæ are fed for several days on a jelly-like substance consisting of regurgitated food mixed with a secretion from glands in the heads of the workers and poured out from their mouths. After this the workers and males receive beebread, a mixture of pollen and honey, while the young queens are continued on their diet of elaborated material, "royal jelly," furnished by the workers. When for any reason a hive loses its queen, the workers proceed to break down the walls between three adjacent cells containing worker larvæ, kill two of the occupants, and bring the third to maturity as a queen by use of royal jelly. The first eggs laid in the spring produce workers; the males are produced from unfertilized eggs laid by the queen. When the larva is full grown no more food is supplied to it, and the cell is sealed with a waxen cover. Within this prison

the larva spins a cocoon and changes to a pupa. Within three weeks from the laying of the egg the worker bee cuts a hole in the covering of its cell and emerges. A queen is produced in somewhat less time; a drone requires slightly longer.

In late spring or early summer, as the colony has increased in size, the time approaches for one of the new queens to appear from the pupal stage. A peculiar noise may be heard, made probably by the wings of the imprisoned queen. Part of the ordinary work of the hive is neglected, and the old queen rushes forth with a large number of the community, generally alighting in a palpitating mass on some neighboring tree or other support. This is the "swarming" of the bees. If provided with a new hive, they will generally settle down quietly in their new home. Bees are particular as to the state of the weather at the time of swarming, appearing only when the sky is clear. The workers carry a store of honey in their crops, as if prepared for a long trip, which in a state of nature may often have occurred before the bees could find a hollow tree or a crevice among rocks suitable for a home. The swarming serves the purpose of lessening the chances of a total extinction of the species, by increasing the number of communities.

Meanwhile the new queen appears in the old hive, and after a flight in the air with the drones, during which fertilization occurs, she settles down to her duty of egg-laying. This flight and the swarming are the only occasions upon which the queen leaves the hive. The number of swarms thus given off varies with the size of the original community and seems to depend somewhat on climatic conditions. It is not uncommon to have three swarms in a season. When the community is to send out no more swarms, the queen is permitted to sting the other young queens to death. If by any chance two queens meet, a conflict begins at once, and the

usual result is the death of one of them. This is often spoken of as due to the jealousy of the queens, but it may have a meaning in connection with the necessity the community is under of sending out swarms to maintain a separate existence. The sting of the queen is used only in these battles and in slaying the young queens. At the end of the swarming season the workers set upon the drones and kill them, casting their dead bodies out of the hive. The queens live for several years, depositing two or three thousand eggs a day during a part of the season. The workers live, as a rule, less than two months.

The wax of which the cells of the comb are composed is secreted in the form of thin plates in "wax pockets" beneath some of the abdominal somites. While preparing this, full-fed workers cling motionless to the cells in the upper part of the hive, and in about twenty-four hours the wax appears. This is removed by other workers and is used in construction. Honey is made for food for the young and for winter consumption of the colony. The pollen of flowers is brought to the hive in "pollen baskets," clear spaces surrounded by hairs on the outer side of the hind tibiæ. The basal joints of the hind tarsi are much enlarged and are used as brushes to gather the pollen.

Bumblebees and Guest Bees. The bumblebees (*Bom'bus*, Fig. 57) are social bees, having homes in fields, in deserted mouse nests, and similar places. The nest is begun early in the spring by a female which has wintered, and, as with the social wasps, the burdens of the home are turned over to the young workers when they emerge. Late in the season other females and males appear, but there is no swarming as with the honeybee. On the approach of cold weather the workers and males die. The honey made is strong-smelling, but much sought after by boys in the country, perhaps as much for the danger connected with its capture as for the sake of the

honey itself. Boys in the West rob the bees by placing a gallon jug partially filled with water in the vicinity of the nest and thoroughly arousing the members of the community. The boys make good their escape to a safe distance, and the bees, perceiving the jug, fly to its open mouth, which

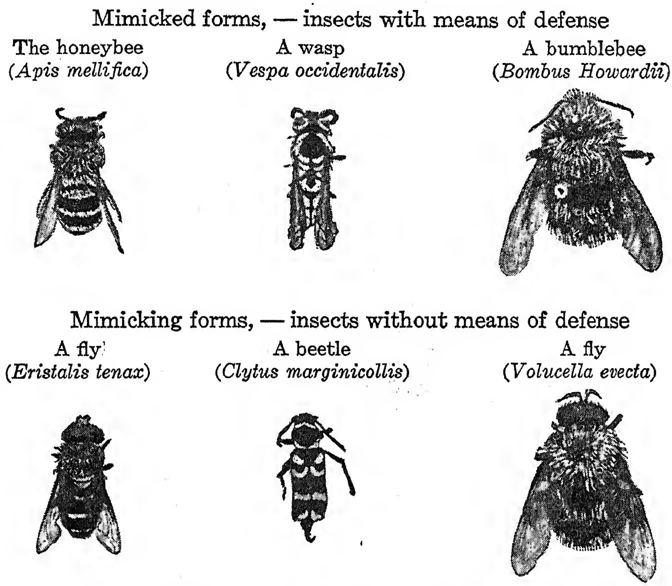


FIG. 57. Mimicked and mimicking insects. (Natural size)
From photographs [1]

echoes the buzzing of their wings. Some bees fly into the mouth of the jug, thus adding to the noise and attracting others. It is said that with two disturbances of the nest the worker bees can all be captured.

The red clover, of such great value as a hay crop, depends almost altogether upon bumblebees for fertilizing the flowers. The funnel-shaped flowers are too deep to allow

[1] From Hunter's *Studies in Insect Life.*

the tongue of the honeybees to reach the nectar at the bottom. But the bumblebees reach the bottom of the cup and in so doing carry pollen from one flower to another. The early blossoms of the clover come out in the spring before many bumblebees are on the wing. These rarely produce seeds. A farmer usually depends on his second cutting of the clover for seeds, because the second crop is in blossom after the bumblebees become active.

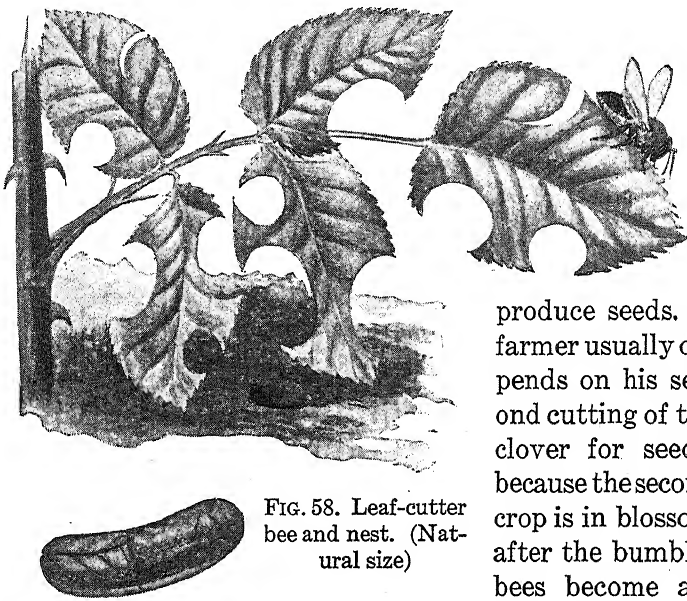


FIG. 58. Leaf-cutter bee and nest. (Natural size)

There are several bees called guest bees (*Psith'yrus*), which live in the nest of the bumblebees, apparently on good terms with them, though they do not, so far as known, perform any useful function. Their eggs are laid with the eggs of the bumblebees, and the larvæ feed on the food which the bumblebees provide for their own young. Some of the guest bees resemble their hosts quite closely; others are different in appearance, so that it cannot be said in all cases that the bumblebees are deceived by the resemblance. One effect of the dependence of the guest bees on their hosts is seen in

the absence from the hind legs of the former of the pollen-collecting and pollen-carrying organs. It has been observed that the bumblebees sometimes resent the introduction of one of the guest bees into their nest, though they may later become accustomed to it and make no further trouble.

Solitary Bees. There are solitary bees, just as there are solitary wasps. Their habits are very diverse; some make nests of mud or dig tunnels in the ground; some are carpenters, boring into wood; and others are leaf cutters, taking circular pieces out of leaves, which they use to line their nests. Fig. 58 represents the work of one species, the leaf-cutter bee (*Megachi'le latima'nus*), which makes long tunnels in wood or in the ground. The eggs are laid singly on a paste of nectar and pollen, which is placed carefully in a leaf-lined cell and covered with a circular lid. Several such cells are generally to be found in one nest.

Ants. Ants have long been considered models of industry. In many respects some of the features of their life history are the most remarkable of anything in the insect world. So specialized have the members of the community become in some cases that there are not only males and females, but large and small workers (workers major and minor), and soldiers for the defense of the colony. Ants build nests in the ground, piling up the material taken out for their burrows in the characteristic ant hills; or they make tunnels in wood. Some inhabit the interior of thorns or the hollow stems of grasses; others live on certain trees, from which they obtain all their food, forming a kind of bodyguard which defends the tree from the attacks of various enemies. The food of ants is both animal and vegetable, the former consisting of other insects, the latter of plant fluids. They are also extremely fond of the sweet substance called honeydew, furnished by the aphids and some few other insects.

The eggs are, of course, extremely minute, and hatch into footless larvæ (Fig. 59, *D*), which resemble those of the bees and wasps. The workers (Fig. 59, *A*) take great care of the young, feeding them and moving them about

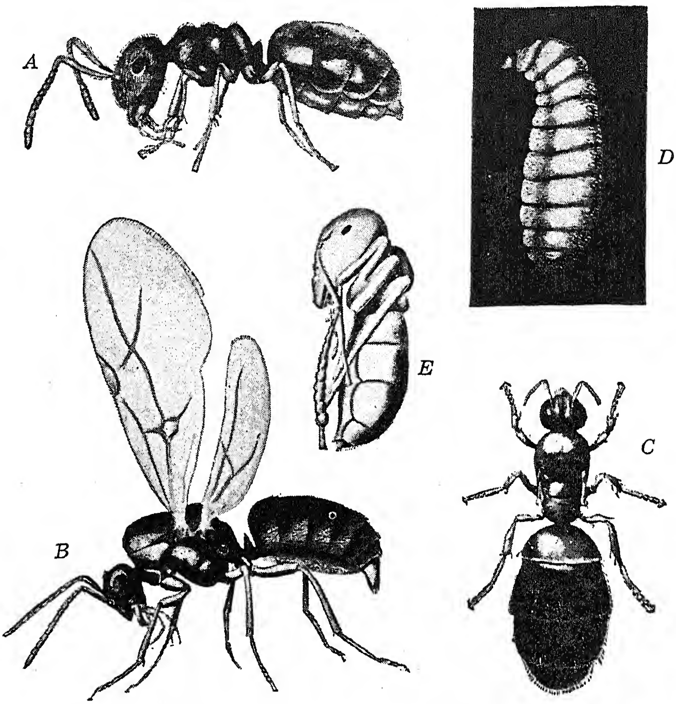


FIG. 59. The cornfield ant. (Much enlarged)

A, worker; *B*, winged male; *C*, wingless female; *D*, larva; *E*, pupa. (From Forbes, Illinois State Natural History Survey)

in response to changes in temperature and amount of moisture. Among ants generally, the workers feed not only the young but even give up food to each other, when this is demanded by a stroke of the antennæ. The pupal stage (Fig. 59, *E*) is generally passed in silken cocoons. These

are the so-called "ant eggs," which are the objects of much solicitude when a nest is exposed. The imagoes are unable to escape from the pupal case without the help of the workers. The males and females are at first winged (Fig. 59, *B*) and take flight in great numbers into the air on some warm day in spring. At this time fertilization occurs. On their return the males soon die, and the females, stripping off their wings (Fig. 59, *C*), become the mothers of colonies. The females can be distinguished from the workers by their larger size and the presence of well-developed ocelli.

Many other insects, especially beetles, live habitually in the nests of ants, and, in some cases at least, seem to perform some useful function, — acting as scavengers, for instance. These cases, like that of the bumblebees and guest bees, may be cited as illustrations of *commensalism* (Lat. *com* (= *cum*), "together"; *mensa*, "table"), an association of one species of animal with another for support or advantage, but not as a parasite.

An illustration of coöperation between two different species of animals is shown in certain ants and aphids. As mentioned in Chapter IV the cornfield ant (*La'sius*, Fig. 59) collects eggs and young of a species of aphid and guards them throughout the winter in burrows, thereby providing a constant supply of honeydew. Some ants build a shelter of wood pulp or mud over colonies of aphids, which are crowded on a branch, from which they derive their nourishment. These aphids are often spoken of as the cows of the ants. In these cases the relation between the ants and aphids is clearly of a more intimate character than the association of the bumblebees and guest bees; and the advantages are mutual, for while the ants secure a constant supply of food, the aphids receive care and a certain amount of protection against their enemies. This association is spoken of as *symbiosis* (Gr. *syn*, "together"; *bios*, "life").

Several species, including the little black ant and the minute red ants, become household pests.

The honey ant of Texas (*Myrmecocys'tus mel'liger*) has one set of workers peculiarly modified to act as storage vessels for sweets. The abdomens of these are distended with a store of grape sugar, till they are as large as a currant. These workers cling to the roof of the nest, and in times of famine can be drawn upon for food by the other workers.

The agricultural ant (*Pogonomyr'mex barba'tus*) clears large spaces, often several feet in diameter, cutting down all vegetation growing thereon, and rears a grain-bearing grass, storing its seeds in underground chambers. Several kinds of ants have the habit of attacking other kinds and carrying off their pupæ. In one (*Formi'ca sanguin'ea*), a small reddish species, the habit has become firmly fixed, and periodical raids are made upon a larger black species, which are afterwards raised in the nests of their captors. One ant of a slave-making tendency (*Polyer'gus rufes'cens*), found in Europe, has carried the habit so far that it has lost the power of feeding and taking care of itself, depending entirely on the exertions of its servants. The wars of ants have been known for a long time, and many accounts are extant of the fierceness of the struggle between opposing armies.

Gallflies and Ichneumon Flies. The gallflies form many of the swellings on plants, known as galls. A common gallfly of the oak (*Amphib'olips*) is shown in Fig. 60. The gall is caused by the female laying an egg in the leaf tissue, which swells up when the larva hatches. The young feed on the material of the gall until they are ready to go into the pupal stage. Many of these galls harbor also guest gallflies, living with the others as commensals.

Closely allied to the gallflies are the ichneumon flies. One species deposits its eggs in the burrows of a wood-boring

larva by means of its long ovipositor, and the ichneumon larva on hatching moves along in its burrow until it finds its host, when it fastens itself to it and destroys it by sucking its blood. Many of the ichneumon flies are true parasites in the larval stage, the eggs being deposited on the skin

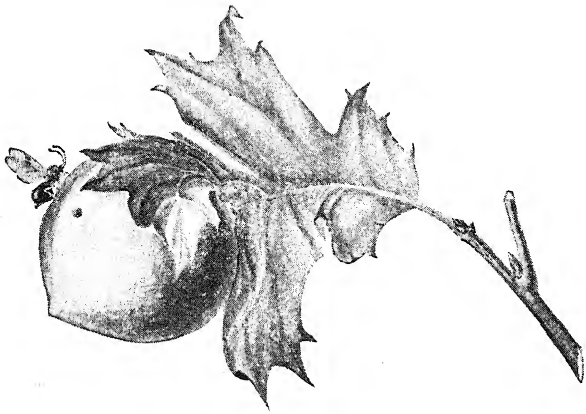


FIG. 60. Gallfly. (Natural size)

or in the body of the caterpillars, upon the fluids of which the ichneumon larva feeds. The pupal stage is generally passed within the body of its victim.

Sawflies. The sawflies have the base of the abdomen as broad as the thorax. The ovipositor of the female consists of a pair of saws, which are used to make slits in the leaves and stems of plants, in which she deposits her eggs. Fig. 61 shows the American sawfly (*Cim'bex america'na*), our largest species. The larva looks like the caterpillar of a butterfly or moth, but has more legs. It has the curious habit of coiling the posterior end of its body about a branch, as shown in the illustration. It forms a brown cocoon, in which the winter is passed in the ground.

Larvæ of the currant sawfly (*Pteronid'ea ri'besi*) fre-

quently become so very abundant that they destroy all the leaves of currant and gooseberry bushes in the early spring.

Definition of Hymenoptera (Gr. *hymen*, "membrane"; *pteron*, "wing"). The insects which we have been considering in this chapter all agree in possessing mouth parts

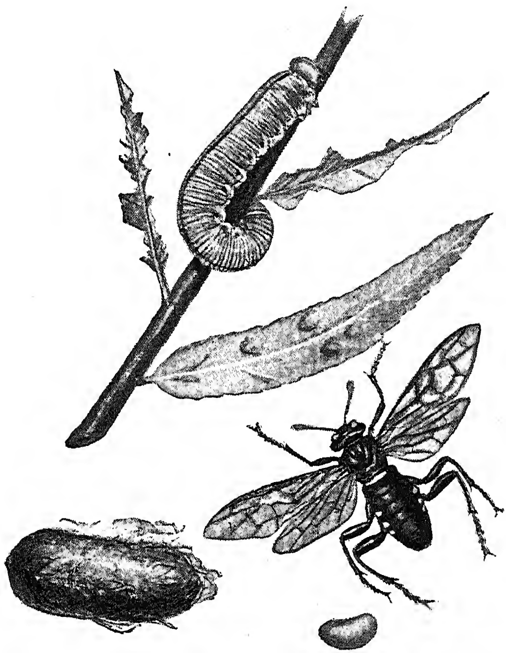


FIG. 61. Metamorphosis of sawfly. (Natural size)

adapted both to biting and lapping, and four membranous wings with few veins. The order is called Hymenop'tera. A structural peculiarity is the union of the first abdominal somite to the thorax. Consequently what appears to be the division between the thorax and the abdomen really comes after the first abdominal somite. The Hymenoptera undergo complete metamorphosis.

CHAPTER X

THE INSECTS: HEXAPODA

Though numberless these insect tribes of air,
Though numberless each tribe and species fair,
Who wing the moon, and brighten in the blaze,
Innumerous as the sands which bend the seas;
These have their organs, arts, and arms, and tools,
And functions exercised by various rules.

H. Brooke, Universal Beauty

Hexapoda (Gr. *hex*, "six"; *pous* (*pod-*), "foot"). The previous chapters have been devoted to *entomology*, that branch of zoology which treats of insects. The insects belong to the class Hexap'oda, the most numerous of all classes of animals, comprising four fifths of the animal kingdom. Insects are built externally upon the plan of a series of somites, grouped in three regions and with jointed appendages on two of them, — the head and thorax. Except in very few cases, where this number is reduced, the imagoes have six legs. Hexapods are found in every variety of situation, though they are, as a whole, adapted to life on the land and in the air. A system of tracheæ is universally present in the imagoes, though the young of some species have gills for breathing in the water. These gills are usually supplied with tracheæ, but in some species blood gills are found.

The hard, chitinous covering (exoskeleton) necessitates frequent molts to provide for increase in size. Among many of the lower orders of insects the young gradually grow into the adult form without any change more sudden or conspicuous than the appearance of the functional wings at the last molt. This type of gradual change to the adult form, or

incomplete metamorphosis, is illustrated by the grasshopper (Fig. 5) and the squash bug (Fig. 23). Throughout their development the young, or nymphs, are active and with few exceptions pass through no inactive resting period.

The most marked change of form is seen in the higher insects, the Coleoptera (Fig. 35), Lepidoptera (Figs. 38, 39), Diptera (Fig. 47), and Hymenoptera (Fig. 59). In all of these the egg hatches into a worm-like larva totally unlike the adult. After several molts and great increase in size the larva stops feeding and becomes inactive. This resting stage, which is usually very different in appearance from the larva, is called the pupa. From this pupa the adult, or imago, finally emerges. This cycle of stages, passing from egg through larva and pupa to the adult, is called complete metamorphosis.

Along with the changes in body form in insects having complete metamorphosis there are even more striking changes going on inside the body. The internal organs of the larva rarely become the organs of the imago. The tissues of the larva become reconstructed to form the organs of the adult. This process of reconstruction is carried on very largely by the white blood cells, or phagocytes, which destroy the larval organs and aid in building up the new organs for the adult. In the fly maggot the wings and legs do not become evident until the adult emerges from the pupa. But even in the larva they begin to develop as small buds, or "imaginal disks," inside the body.

Insect Behavior. Insects are provided with a nervous system and sense organs that enable them to be affected by conditions that exist outside their own bodies. These sense organs are of various kinds, and for some of them we have no idea as to the functions they may perform. The other sense organs more or less closely resemble those found in the human body, and we therefore assume that they serve

the insect in much the same way that similar organs serve man. Experiments prove conclusively that insects feel, see, hear, taste, smell, and we know that they are able to recognize differences in temperature. But the remarkable thing is that many insects have additional sense organs which we are entirely unable to interpret because we have nothing like them in our own bodies. In studying other animals we are limited by our understanding of our own senses, and find it hard to appreciate the fact that what we see with our eyes and hear with our ears may not be exactly the same as effects produced on the nervous system of another animal. As human beings we view our own actions in the light of intelligence. When we attempt to explain the actions of other people or of other animals, it is only with difficulty that we can interpret on the basis of what we actually observe. When a man is lost in the woods at night he walks toward any light, reasoning that he may find help. But this does not make it safe to assume that a moth flies toward a light because of any intelligent motive. In fact the movement of the moth in this instance is involuntary.

Most of the actions of insects are purely reflex, involving none of the higher types of mental activity known as intelligence. When a stimulus acts upon an insect and causes the body to take a definite position there is no choice of action on the part of the insect. The response under these conditions is called a *tropism.* Tropisms are purely mechanical or involuntary responses to a stimulus, not involving intelligent choice of action.

It is difficult to draw the line between these automatic reflexes and the acts which are spoken of as *instinctive.* An instinctive act is one which an individual performs without ever having been taught. When a wasp paralyzes spiders and places them in her nest to serve as food for her unborn young there is small possibility that she has any prevision

or intelligent knowledge of the young not yet born, much less any precise understanding of their needs. Yet the wasp gathers the spiders without being taught to do so. Similarly when the butterfly selects a certain kind of plant on which to lay the eggs her act is not intelligent but probably a combination of instincts and reflexes.

Among the higher insects, especially among the social Hymenoptera such as the wasps and ants, many observations have been made upon actions that are interpreted as involving intelligence. In many of these the enthusiasm of the observer has run away with his judgment. There is an impression that ants behave with a high degree of intelligence, yet when anyone studies them carefully he finds that in many instances they perform their tasks in a purely reflex, mechanical way and show no ability to modify their actions when conditions are changed for them. One observer noticed that a wasp going diligently about the feeding of young, bit pieces from a larva and persisted in trying to get them into the mouth of the dead larva from which they were cut. It is really doubtful if even the Hymenoptera have any power of abstract *reasoning*. The actions of most insects thus seem to be chiefly the lower types of behavior though intelligence may play some part.

Man versus Insects. Professor S. A. Forbes of the University of Illinois has aptly expressed the struggle between insects and man:

> We commonly think of ourselves as the lords and conquerors of nature, but insects had thoroughly mastered the world and taken full possession of it long before man began the attempt. They had, consequently, all the advantage of a possession of the field when the contest began, and they have disputed every step of our invasion of their original domain so persistently and so successfully that we can even yet scarcely flatter ourselves that we have gained any very important advantage over them.

Economic Importance of Insects. According to the report of the Secretary of Agriculture for 1925, about 30 per cent of our entire population now live on farms. The gross income from farm products in 1925 was over twelve billions of dollars. When it is considered that our crops are attacked not by one but often by many different insects, and that, according to the estimate of one of the state entomologists of New York, there is no crop cultivated which infesting insects do not diminish by at least one tenth, it is plain that the economic relations of insects to agriculture are extremely important. Nearly every order has its injurious forms. Thus the Orthoptera has its locusts; the Hemiptera, its plant bugs; the Homoptera, its aphids; the Coleoptera, its wireworms and beetles; the Diptera, various flies; and almost the whole army of the larvæ of the Lepidoptera feed on plants.

Control of Crop Pests. In the preceding chapters frequent mention has been made of insects injurious to native and cultivated vegetation. Regardless of whether the damage is by adult or immature insects it assumes one or the other of two forms, depending upon the type of mouth parts possessed by the attacking insect. Chewing insects devour the tissues of the plants, and sucking insects rob them of their sap, so that the plants wilt and become weakened or die (Fig. 62). In either case the old proverb of "an ounce of prevention is worth a pound of cure," holds true. The United States Department of Agriculture, state departments of agriculture and individual entomologists have long studied the various insect pests of importance to agriculture and have worked out many methods of control and prevention of injury. For destruction of chewing insects, poison sprays and powders are applied to the plants to be protected. The insects die upon eating these poisons. Such treatment is wholly ineffective for sucking insects. They are controlled

by what are called contact insecticides, — substances which kill when they touch the body. Oil emulsions, nicotine compounds, insect powders, corrosive materials such as certain combinations of lime and sulphur, are used in the war against sucking insects. As an indirect protection of crops many preventive measures have been developed. These are based upon a knowledge of life history and of habits other than feeding habits. Fall plowing kills many insects

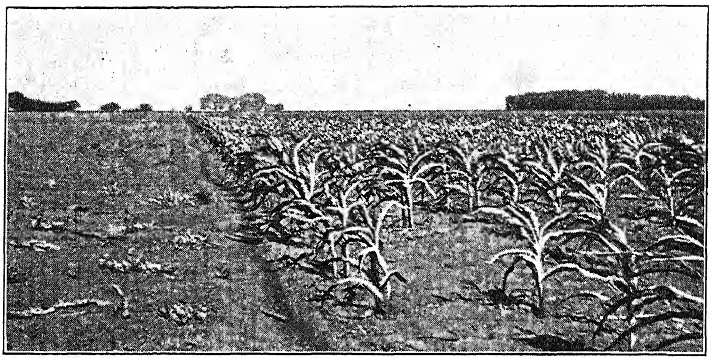


FIG. 62. A cornfield in which a band of road oil was placed as a barrier after the field had been attacked on one side by chinch bugs

In the part of the field to the left of the line every plant was destroyed. (After Illinois State Natural History Survey)

which would live through the winter if the ground in which the larvæ or pupæ are living were not disturbed. Rotation of crops is a big factor in insect control, for a field constantly planted with the same crop becomes a breeding place for the insect enemies of that crop. Some of the very worst crop destroyers, such as the chinch bug (Figs. 24 and 62) and the Hessian fly (Fig. 52), are held in check by keeping fields free from old straw and vegetation in which these insects seek shelter for the winter.

If it were not for civil war among the insects man would have little chance to compete with them. Lady beetles

(Fig. 33) feed upon scale insects and plant lice. Several entire families of Hymenoptera live as parasites on other insects and kill many harmful species. Diseases are not limited to the higher animals. Bacteria and fungi attack and kill some of man's worst insect enemies.

Insects of the Household. Attention has been called to the unsanitary habits of cockroaches living in houses. Clothes moths, buffalo beetles, and crickets as destroyers of articles of cloth and other organic material (for example, fur and feathers) have been discussed in earlier chapters. These are but the beginnings of the invasion which insects carry against man into his household. The larvæ of beetles and of Lepidoptera attack and destroy or render unusable his stored food materials. Cereals become infested with webworms, the larvæ of minute moths. Beans and nuts are destroyed by larvæ of weevils belonging to the Coleoptera. Blowflies lay their eggs on meat that is exposed to their attack, and the developing maggots feed thereon. Dr. Britton, state entomologist of Connecticut, in 1917, estimated that it costs the American people two hundred million dollars a year to feed insect pests of stored foods alone. These are but a few of the aggressors against man in his private domain, the home.

Some insects are even more bold and, if unsanitary conditions permit, will attack man himself. Body and head lice and bedbugs feed upon the human body if conditions favorable for them are permitted to exist. In some localities fleas become so abundant as to make life miserable by their bites. Unless houses are kept screened, flies and mosquitoes render man at least uncomfortable and, as explained in the next section, even endanger his life.

Insects and Disease. Malaria is sometimes said to have been one of the big obstacles to the economic progress of the human race. Sir Ronald Ross, the Englishman who proved

that the bite of the mosquito is the only means of spreading malaria, estimated that in India alone more than a million persons die annually of this disease. But the outright deaths are but a small part of the ravages of malaria. Dr. L. O. Howard of the United States Department of Agriculture estimates that this disease in the United States alone is responsible for a financial loss of not less than one hundred million dollars each year. Yet malaria is doomed if mosquitoes are exterminated.

Yellow fever, which until the opening of the twentieth century was one of the most dreaded diseases in this country, depended entirely upon the bite of the mosquito (*Aëdes*) for transmission. Dr. Reed with his coworkers, Carroll, Lazear, and Agramonte, working in Cuba, discovered the relations of mosquitoes to yellow fever. Dr. Reed, Dr. Carroll, and Dr. Lazear gave their lives directly or indirectly in one of the most unselfish personal sacrifices in the interest of mankind. The knowledge growing out of their experiments has saved millions of lives, and today yellow fever (Fig. 63) is entirely wiped out of the United States.

The importance of understanding the relation of insects to disease is now well acknowledged. Yellow fever had completely disappeared from the United States because of successful campaigns against the mosquitoes transmitting the disease before anyone knew what organism the mosquito is responsible for carrying. Professor Noguchi, a Japanese scientist working in this country, showed in 1918 that yellow fever is due to an organism called *Leptospira.*

In both malaria and yellow fever the disease germs undergo a necessary part of their development in the body of the mosquito transmitting them from one person to another.

Typhoid fever and dysentery are two diseases which the house fly is responsible for spreading. The germs of both these diseases are very abundant in the intestinal wastes

passed from the bodies of infected persons. Where fecal matter is not properly disposed of, flies, because of their filthy habits, get disease germs on their feet and bodies.

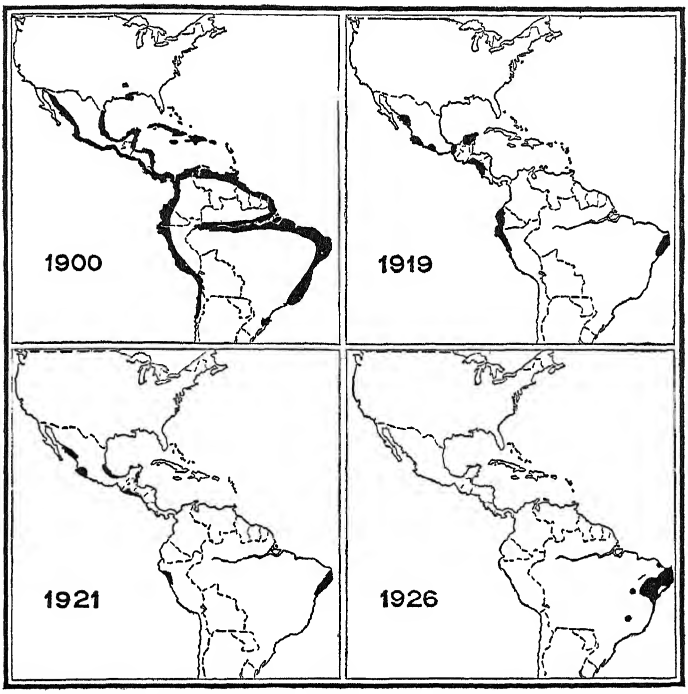


FIG. 63. Maps showing the effects of control measures against yellow fever Yellow fever areas shown in black. (Courtesy of the International Health Board)

Then, when they alight upon food material it becomes contaminated with germs, and anyone eating it is liable to contract the disease.

During the World War there was a great increase in our knowledge of the relations of insects to disease. Lice are responsible for transmitting typhus fever and also trench fever, both of which were so prevalent during the war.

Bubonic plague, or the "Black Death," which swept Europe and Asia during the Middle Ages, killing millions of people, is another insect-borne disease. Rat fleas inoculate the germs into the human body by their bite. One reason why this disease spreads so rapidly is the fact that the germs which produce the plague live in rats and are thus carried by ships to all parts of the world.

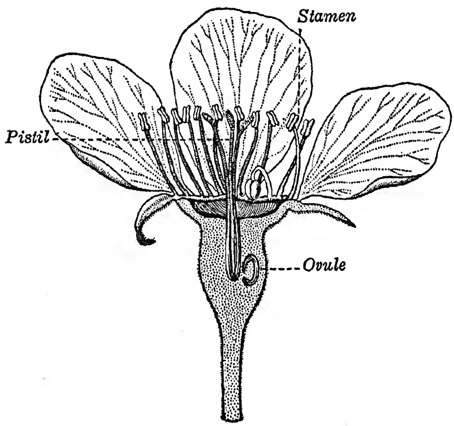


FIG. 64. Diagram of pear flower
Courtesy of the United States Department of Agriculture

Relations between Insects and Flowers. In order to make seed, the flowering plants must have the pollen furnished by the stamens (Fig. 64) carried to the pistil of the same kind of plant. The pollen is necessary to the fertilization of the ovule, which later grows into the seed. Continuous pollination of a plant by pollen which it furnishes from its own stamens has been found to be detrimental to the vigor of the seeds. We find in nature many devices to insure fertilization by pollen from another plant of the same kind,—that is, by cross-pollination.

Some plants have the stamens and pistils so placed in the flower that no pollen can fall from one to the other; some ripen their stamens and pistils at different times. Many have the stamens and pistils on separate plants, and a great number, though the stamens and pistils are close together, are wholly or partially sterile to their own pollen and "set" their seeds only if the pistils receive pollen from the sta-

mens of another plant of the same species. This is the case with many of the fruit trees.

The wind carries pollen for some plants which have their stamens and pistils more or less exposed, but a great number of plants, especially those with the most beautiful flowers, depend on insects to bring about pollination. So far has this dependence gone that, in many cases, plants have become unable to pollinate themselves. It is now clear that the color, scent, nectar, and form of flowers, in many cases, have been developed in connection with insect visitors. The insects most concerned in the pollination of flowers are flies, butterflies, wasps, and bees.

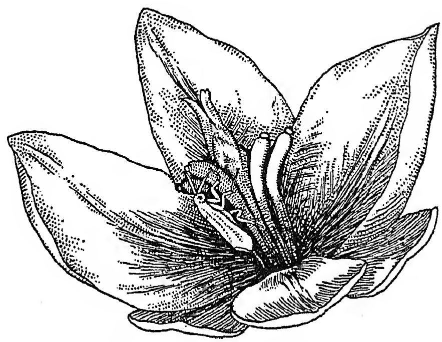


FIG. 65. Yucca moth. (Natural size)
After Riley

Some insects visit flowers for the sake of the nectar. Pollination results from the insect brushing itself against the pollen-bearing organs and subsequently rubbing this pollen on to the pistil in a neighboring flower in the search for nectar. But the case of the yucca moth (*Tegetic'ula*, Fig. 65) is somewhat different. The yucca moth is a white moth a little over a centimeter (about half an inch) long, which lives in the flower of the yucca, or Spanish bayonet, a familiar plant of the dry southwestern plains. During the day the female remains quiet, but at dusk (in the breeding season) she begins laying her eggs within the pistil of the flowers, among the ovules, which, when the flower is fertilized, are to grow into seeds. Upon these seeds the larva will feed. If this were all, there would be no peculiarity

deserving of mention; but the female goes a step further and makes sure of a supply of seeds for the larva by collecting pollen from the stamens and thrusting it into the pistil. The advantage to the larva is obvious, since its supply of food is rendered certain; the advantage to the plant probably lies in the fact that not all the seeds thus provided are eaten by the larva before reaching maturity. This association may be cited as an illustration of symbiosis.

As mentioned under the topic of bumblebees, these bees are very largely responsible for pollenizing the red clover. The honeybee is an important partner of the apple, pear, blackberry, and raspberry, aiding them by insuring pollination. In the milkweed flowers the pollen is borne in V-shaped packets. As a wasp or a bee visits a flower to get the nectar, the pollen masses become attached to its feet and are carried away by the visitor. The structure of the milkweed flower is such that when the insect visits another flower the packages of pollen attached to its feet slip into grooves which bring them into contact with the pistils, thus insuring fertilization of the flower. The pollen masses in some instances become so firmly attached that the insect is held prisoner. The early cultivation of Smyrna figs in this country was unsuccessful. It finally became known that small wasps essential for pollinizing the flowers were lacking. When these insects were introduced into California, the fig industry became established.

CHAPTER XI

CLASSIFICATION AND DISTRIBUTION OF INSECTS

The mute insect, fix't upon the plant
On whose soft leaves it hangs, and from whose cup
Drains imperceptibly its nourishment,
Endear'd my wanderings.

WORDSWORTH

Nomenclature and Classification of Insects. In order to write intelligently about animals, it is necessary that naturalists should have some uniform system of naming, or nomenclature, since the common names of animals vary not only in the different countries and languages but even in different parts of the same country. It will be noticed that each insect, when first spoken of in these chapters, is accompanied by a scientific name printed in italics. Thus the Rocky Mountain grasshopper is *Melanoplus spretus*; the common red-legged grasshopper, *Melanoplus femur-rubrum*; the lesser grasshopper, *Melanoplus atlanis*. These different kinds or *species* of grasshoppers differ in size, color, and habitat, and they each receive a different specific name, as *spretus*, *femur-rubrum*, and *atlanis*. They agree in other characteristics, such as the general structure, size, and proportion of their parts, and they are therefore placed in the same group, or *genus*, — *Melanoplus*. The word "genus" is thus seen to be a term of wider application than the word "species." A genus may include one or several species. The generic and specific names make up the complete scientific name of an animal. The names are always taken from the Latin or Greek, or are Latinized in form, so that they are understood by all scientific men.

They often refer to some striking characteristic of the animal; thus, *Melanoplus* means "black armor," in allusion to the dark-colored exoskeleton. Sometimes the reference is to the locality where the animal is found, as *atlanis*, referring to the Atlantic states; sometimes the name is given in honor of some student of animals, as *Darwin'ii*, named after the naturalist, Charles Darwin. The scientific name first given to an animal, if accompanied by a description, is the name it must bear, and the species is known under that name wherever found. This system of nomenclature was introduced by Linnæus.

The words "species," "genus," and the other terms applied to groups of animals are man's invention, for his convenience in scientific description. Individuals which resemble each other in a large number of characters — and especially if the individuals are able to interbreed — are usually said to belong to the same species. The test of interbreeding, while of almost universal application, is not invariably a means of distinguishing the species, since in some cases two different species can produce offspring (called hybrids), though the latter are usually not fertile, — that is, they are not themselves capable of producing young.

Often within the limits of a single species there are groups of individuals which vary from the others in one or more characters. Especially is this true of those species with a wide range, living under diverse conditions. In such cases the different forms which the species assumes are termed *varieties*, and a varietal name is sometimes added to the generic and specific names. We have already referred to the seasonal variations of the swallowtail butterfly.

The different genera are arranged in groups, or classified, according to their resemblances and differences. A number of genera which show similar structural characteristics of more general character than those used to constitute a genus,

make up a *family*. Thus the grasshoppers of the genus *Melanoplus* and those of all the other genera having short antennæ combined with certain other characters in common, are placed in the family Locus′tidæ. The katydid and other green grasshoppers, with many meadow species, belong to an entirely different family. The crickets (Gryl′lidæ) and the cockroaches (Blat′tidæ) are allied to both of the grasshopper families. By common consent family names end in -idæ. Families are united to form *orders*, and orders in turn make up *classes*. The largest and most important of the orders which make up the class Hexapoda have already been discussed. As we shall see later, the classes are united to form *phyla* (sing., *phylum*), the primary divisions of the animal kingdom.

The Simplest Insects. In the study of insects we began with the grasshopper because it is large enough to study easily. There are two orders of insects which are even simpler in structure than the grasshoppers and therefore are said to be "lower" than the Orthoptera. These are the Thysanu′ra, or fish moths, and the Collem′bola, or springtails. The insects of both these orders lack wings altogether. In their development these lowest insects have no metamorphosis, for the young immediately upon leaving the eggs are almost exactly like their parents. Because of their simple structure many people believe that these are much like the insects which first appeared upon the earth in some past geological time.

Thysanura. Glue is frequently eaten off the bindings of books, and wall paper is often loosened from the walls, by a minute, wingless, silvery insect, the fish moth, or silverfish (*Lepis′ma sacchari′na*, Fig. 66). In spite of their small size and retiring habits, they may cause great damage to libraries and in households because of their appetite for paste, starch, and such substances.

Collembola, or Springtails. These wingless insects, still smaller than the Thysanura, are of very little importance. They occur on the surface of water and under leaves and stones. At times they become so abundant on snow that they are called snow fleas. They make surprisingly quick jumps by extending a spring-like tail, which at rest lies underneath the body. Until they jump into the air they might readily be mistaken for minute particles of soot or dirt.

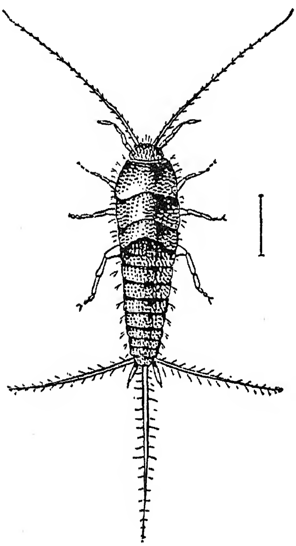
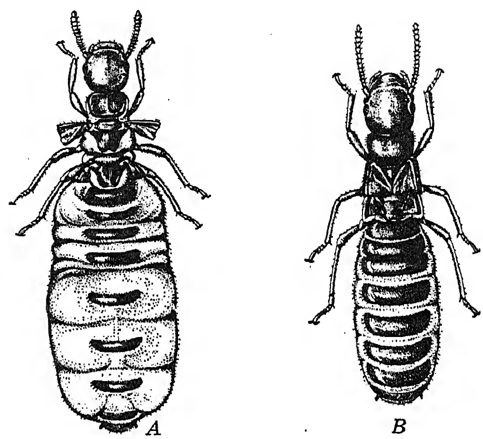


FIG. 66. Fish moth. (Enlarged)
After Marlatt

Isoptera, or Termites. Often in old logs, stumps, or under stones swarms of small white insects resembling ants are seen (Fig. 67). They hollow out galleries in wood and soil similar to those made by ants. Although these insects are often called white ants, they are not ants and are not closely related to them. They belong to an order known as the Isop′tera, which is but slightly higher than the Orthoptera. Like ants, hundreds or even thousands of individuals live together, forming a society. There are several classes of individuals. Wingless, white, thick-waisted insects are the workers. They gather food, build the nests, and care for the young. The soldiers are wingless, like the workers, but have very large heads and powerful jaws for the defense of the colony. The kings and queens, or fathers and mothers, have wings. On reaching maturity they fly away in pairs. After this flight they shed their wings. The queen lays eggs which the workers care for.

The termites are especially abundant in the tropics. Some species build large mounds, twelve feet or more in height. Their food is chiefly wood, and they often destroy buildings and furniture. Jamestown, the capital of St. Helena, was largely destroyed by termites and had to be rebuilt on that account. Though less numerous in the northern United States, houses are sometimes greatly damaged by them.



A B

FIG. 67. Termites or white ants. (Much enlarged)

A, female; *B*, male. (From United States Department of Agriculture, *Bulletin No. 1472*)

Degrees of Specialization. The lack of special adaptations or modifications of the various organs marks the ancestral insects as *generalized* forms, as distinguished from their more or less *specialized* descendants of today, in which the organs have become modified to perform different functions. Thus the greatly developed hind legs of the grasshoppers are a specialization in structure, fitting the insect to progress by leaps as well as by walking.

Very different degrees of specialization often exist in the organs of the same species; thus the digestive system of the grasshopper is quite complex, while the separate prothorax is a generalized character, which shows the grasshopper to be allied in this respect more closely to the primitive type than are insects like the wasps, for example, where the three

divisions of the thorax are grouped in one mass. Within the limits of every order there are different degrees of specialization, and there are cases in every order where loss or decline of parts (called degeneration) has been brought about through various causes. Among the May flies the mouth parts of the imago have become degenerate in connection with the short adult life, which lasts only long enough for mating and the laying of eggs for a new generation. In some scale insects the female becomes degenerate in connection with the quiescent life beneath a protecting scale. She loses eyes, antennæ, and legs, becoming very little more than a bag capable of feeding and reproducing. Parasitism also brings about degeneration.

From the study of the forms in which different organs appear in the orders of insects (that is, from the study of morphology, the science of form), the naturalist is able to say which kinds of insects have, on the whole, become most specialized in structure, and which have, on the whole, varied least from the primitive generalized type. While all zoologists agree that the Thysanura and Collembola are the lowest orders of insects, there are many differences of opinion on the arrangement of the other orders. In an introduction to zoology it is not necessary to consider some of the orders which contain only very unusual or uncommon insects.

Generalized Insects. The generalized, or lower, orders which have been taken up in this book are the Thysanura, Collembola, Ephemerida, Odonata, Orthoptera, Isoptera, Homoptera, and Hemiptera. The insects of all these orders agree in having incomplete metamorphosis or no metamorphosis at all.

Specialized Insects. The insects which have complete metamorphosis are generally recognized as the more highly developed. The Coleoptera, Lepidoptera, Diptera, and Hymenoptera are specialized, or higher, orders.

Fossil Insects. We have but a very imperfect picture of the insect life of the past. The remains of any animal of a past time are called a fossil. Contrary to general belief, a fossil is not necessarily an animal which has turned to stone, for many fossils are not petrified. However, most of the records of insects from past ages are preserved for us in the rocks of which the crust of the earth is built up. The agencies whereby fossils have been preserved are commonly as follows: Wherever areas of land are uplifted, the atmospheric agencies of wind and water begin their work of wearing them down again. The worn materials, in the form of clay, sand, or mud, as may be seen today after a rain, find their way in rivulets to lower ground, or into a river which deposits them still lower, finally even to the bottom of the sea. When there, or in a temporary resting place in some lake or pond, the material forms a bed into which the remains of animals may drop. Under favorable conditions their hard parts are preserved in perfect form. The substance in them may be replaced by minerals, and the entire mass consolidated into rock by heat and the pressure of other materials upon it. Even footprints may be made in the soft mud at the edge of ponds, and indelibly preserved in the rocks of later times.

The geologist has worked out in detail the order in which the rock material of the world has been laid down. By studying the fossil remains of living things the zoologist can picture something of the life of each of the great epochs in the earth's history, though, owing to the conditions of preservation, by far the greater part of the record has been lost. It is as though we should try to get a connected idea of the history of the United States from a book from which had been torn the whole of the early voyages, much of the colonial period, and many pages from the story of the Revolution, the Civil War, and later history. Unfortunately the geo-

logical record is especially incomplete with regard to the insects, so that it does not give us much help in this particular problem.

Most fossil-bearing rocks are formed on the floor of the oceans. Since insects very rarely live in salt water, it is not surprising that fossil remains of these animals are relatively rare. Coal is a form of fossilized plants of a past age. Some of the best specimens of fossil insects are found in the coal deposits. Especially around the Baltic Sea, another interesting type of fossil insects has been discovered. These are the perfectly natural-looking specimens entombed in fossil amber.

Of the remains of winged insects which have so far been discovered, the earliest are those belonging to the orders Orthoptera, Hemiptera, Ephemerida, and Odonata.

Distribution of Insects. Insects occur in every part of the earth which man has explored. Even in the Arctic and Antarctic regions insects are not wanting. Although many species are very widely distributed, being cosmopolitan (distributed over practically the whole earth), many others are of very limited range. No one has been able to offer a satisfactory explanation of why the monarch butterfly and many species of beetles have spread over so much of the earth's surface and some other species are found in only a limited locality of but a few miles in extent.

Any condition which tends to limit the distribution of a species to a restricted area is called a *barrier.* To land animals such a barrier may be a mountain range, a desert, or a large body of water. To a desert-inhabiting species it might be a forest. To aquatic animals, waterfalls or rapids are often insurmountable. Temperature conditions are very definite in their effects on the distribution of animal life. Food supply is another important factor. The ocean is a barrier to nearly all land species.

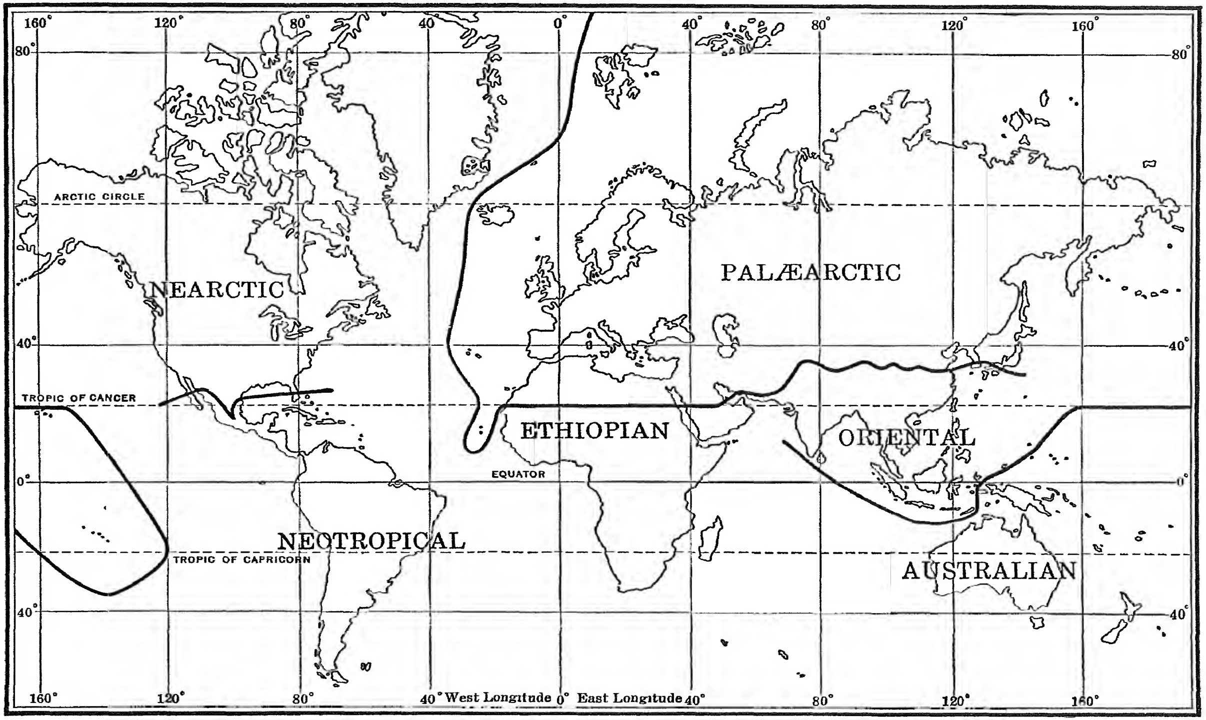


FIG. 68. Map showing the zoological realms

The animal life of any region is known as its *fauna.* Though insects are widely distributed over the earth, a study of the different species shows that there are more or less well-marked areas, each of which possesses its characteristic species. Though much overlapping occurs, as might be expected in the case of animals which can fly freely from place to place, yet on the whole it is possible to separate fairly well-marked regions, the climatic and other boundaries of which have prevented any great intercommunication, thus producing peculiar forms of life in each region or realm. Six realms are very commonly recognized (Fig. 68). These do not exactly agree with the geographical divisions into continents. The animal life of the Americas is fairly distinct from that of the rest of the earth. Here two realms are recognized, the Nearctic and the Neotropical. The boundaries of the six realms are as follows:

1. The Nearctic realm includes all Greenland and North America south nearly to the tropic of Cancer.

2. All Central and South America and the coastal region of Mexico comprise the Neotropical realm.

3. All Europe, Africa north of the tropic of Cancer, and Asia south to an irregular line close to thirty degrees north latitude is called the Palæarctic realm.

4. The Ethiopian realm is that part of Africa south of the Sahara Desert, Madagascar, and the southern tip of Arabia.

5. The Oriental realm includes the tropical regions of Asia, namely, India, Ceylon, and South China.

6. The Australian realm is one of the most distinctive because the animal life is so different from that of the neighboring regions. This includes the continent of Australia, New Zealand, and many of the surrounding islands.

The student who has recently studied physical geography may be able to see some relationship between the divisions of these regions and climatic conditions.

CHAPTER XII

SOME OF THE LIFE PROCESSES

You may bring up a dog on the food of a man, and yet you cannot make a man of him. —John Burroughs

Organ Systems. When we first began to study the insects there was little reason to make comparisons between them and our own bodies. But now that we have finished the study of this group let us begin to make some comparisons between what we have learned about insects and what we previously knew about our own bodies. In spite of the differences in form, we call many of the parts by the same names in the two bodies, chiefly because they perform somewhat similar or identical functions. The leg of a grasshopper with its many joints, its skeleton on the surface and muscles inside the skeleton, is very different from the human leg, yet both of them serve for locomotion. Similarly, in the grasshopper we found organs of digestion and circulation, a respiratory system, an excretory system, and a reproductive system, all of which in functions correspond to parts of our own bodies.

Likenesses of Living Things. In spite of difference in structure there are a few things which all living animals do, no matter how complicated or how simple they may be. They have the power of taking lifeless food material and making it over into part of their living bodies. As a result of the energy which they derive from this food they live and respond to outside forces which act upon them. Finally, they have the ability to grow and produce other individuals

of their own kind. Regardless of how they are constructed or how and under what circumstances they live, there is a striking similarity in the processes of changing food material into the living substance (*protoplasm*) of their bodies and the use of this food for producing energy. Because of these likenesses, and because we are most interested in, and familiar with, human structure, we are going first to review this process in our own bodies. Later, as we study each animal, we may note in what ways it is different from, and similar to, man.

Digestion Defined. Food is taken into the body either as a solid or a liquid. The entire process of digestion consists in changing all the foods to a liquid state which is able to pass through the wall of the digestive tract. In terms of the chemist and physiologist foods may be classed as water, salts, proteins, carbohydrates, and fats. Water and the various salts used as food are capable of being used without change. The other food substances must be changed before they are available for use.

Enzymes. The digestive system produces fluids which act upon the different food substances. The name *enzyme* is applied to the materials in the digestive fluids which bring about digestion.

The peculiar quality of an enzyme is to cause a chemical change in another substance without itself losing any of its own properties. Thus, *trypsin,* the enzyme which acts on proteins, can do so and still remain trypsin. Similarly, the enzyme *ptyalin* acts upon starch, and *steapsin* upon fats.

Why Food is Changed. Let us consider for a moment why it is necessary for an animal to secrete elaborate chemical mixtures like digestive fluids. If we were to examine the alimentary canal, we should find that there are no openings leading from the canal to the body cavity which might permit food to pass directly to different organs. The wall of the

canal is thin, but it is made of small bodies, or cells, which are packed closely together. Water will pass through this membrane easily, but certain other substances, although in a liquid state, will not pass through so readily. Those solutions which pass through an animal membrane readily are called *crystalloids*; for example, solutions of salt or sugar. Liquids which do not pass readily through an animal membrane are known as *colloids*; for example, solutions of meat juice or starch. The action of the digestive fluid is a double one: it changes the state of the solid food *physically*, by rendering it liquid; it changes the state of organic foods (both solid and liquid) *chemically*, giving at the same time to each of the altered food substances a new physical property, namely, that of being able to pass through the intestine wall.

For illustration, we may suppose that a piece of potato which contains a great deal of starch is taken as food. In the mouth and intestine the starch is changed physically by being made liquid or partially so, and it is changed chemically into a sugar compound by the action of the enzyme ptyalin, which is present in the saliva. In the latter state, what was once starch passes readily through the wall of the intestine. A protein substance like meat juice cannot pass, except in a slight degree, through the intestine until it has been changed chemically. This is done in the intestine by the enzyme trypsin, which is produced from the secretions of the pancreas. The changed substance is called a *peptone*. The enzyme steapsin, also produced by the pancreas, separates the fats into compounds known as *glycerin* and *fatty acid*. The fatty acids combine chemically with the alkali in the digestive tract, resulting in compounds similar to soap; the process is therefore called *saponification*. When the proteins are changed to peptones, the starch to sugar, and the fats to glycerin and soaps, then these organic foods

are ready to pass with any inorganic foods — as, for example, salt and water — through the wall of the intestine. The enzymes just discussed are very important and it is only by their activity that many foods are changed in the digestive processes. A considerable number of other enzymes and materials produced by the liver and by glands in the walls of the stomach and intestine aid in digestion.

Absorption. Digested food passes through the intestine wall and mixes with the body fluids, in accordance with a principle known in physics as *osmosis*. It is well known that a crystalloid, like salt or sugar, if placed in a vessel of water, will soon diffuse through the water. In doing so it exerts a certain amount of pressure. This is called osmotic pressure. If a permeable membrane be interposed between a solution of crystalloids and one of colloids, both substances will exert some osmotic pressure, but by far the greater amount is exerted by the crystalloid, because of its greater facility in diffusing through water.

Applying the principle of osmosis to absorption in the intestine, we have crystalloids in the cavity of the intestine, a permeable though not porous membrane (the intestine wall), and colloids in the blood and body-cavity fluid. The digested food diffuses through the intestine wall because of the pressure it exerts in seeking to mix with more water. Food on passing to the blood is changed by the cells of the intestine wall from the crystalloid condition to a colloid, and is henceforth incapable of passing back through the membrane.

Assimilation. The food is transported by the blood in the blood vessels or in the body cavity to tissues, where some of it is transformed into protoplasm. Just how this is done no one has been able to discover, but it is known that the transforming process, which is called *assimilation,* takes place in all tissues that are alive, — for example, muscles and

nerves. We know that the building up of new protoplasm takes place in growth, when new cells are formed, and that it is also made necessary on account of the slow and imperceptible destruction of the protoplasm in oxidation (see below).

It will be helpful at this point to know that of all the food taken into the circulatory system of an animal but very little, except during growth, is actually made into protoplasm. The carbohydrates and the fats that are absorbed, and those that are made from proteins by the protoplasm, together with some unassimilated proteins, are destroyed after they have been stored temporarily in the various tissues of the body, especially in the muscle cells or in the liver.

Respiration. So far we have traced the food through those changes leading to its assimilation by the living animal. Protoplasm and the food materials stored within it are chemical substances which unite rather readily with oxygen. In spite of the fact that oxygen destroys the substance of which protoplasm is composed, there are few animals which are able to exist without oxygen. Oxygen is necessary to life because the union of oxygen with protoplasm and stored food material sets free the energy which is used by the animal in its movements and other life activities. The stored food material and the living protoplasm are broken down, not as wanton destruction but as the only means whereby the animal obtains its energy.

When oxygen combines with the material of a living organism, the process is called respiration. Special organs of respiration are found in most of the higher animals. Thus in man the lungs, in fish the gills, and in insects the tracheæ are organs adapted to supplying the body with oxygen and to giving off certain types of wastes. The essential characteristic of a breathing organ is a thin, moist membrane, with thin-walled capillary blood vessels on one side and air on the other. In man these conditions permit

oxygen to pass through the tissue of the lungs into the blood-filled capillaries and permit wastes to escape from the blood.

In the circulating blood there is a red-colored substance called *hæmoglobin.* Oxygen combines chemically with this, and the compound goes with the blood until it reaches tissue cells which have some food stored in them; then the oxygen combines with the food, which may be carbohydrate, fat, or protein. The chemical union of oxygen with other elements is of the greatest importance in the life of any plant or animal. A simple example of the result of the chemical union of oxygen with another element may be observed in the burning of coal. It is well known that coal is composed chiefly of carbon. When a quantity of coal is heated it begins to unite with oxygen from the air. During this process four phenomena may be observed: first, the quantity of oxygen in the room is reduced; second, the quantity of coal is reduced; third, an invisible gas is formed; and fourth, heat and light are given off.

When oxygen unites chemically with carbon two kinds of gas may be formed, either carbon monoxide or carbon dioxide, or both. The union of a solid element with a gaseous one to form a gaseous compound accounts for the fact that so great a mass of coal disappears in burning, leaving only the mineral ash behind. We call the union of oxygen with another substance *oxidation.*

Forms of Energy. It is important to observe that as oxidation takes place heat and light, which are called forms of energy, are given off. Energy — that is, the power to do work — can be transformed from one form to another; for example, the heat derived by oxidizing coal may be transformed into mechanical energy like that of an engine, and the mechanical energy may be changed into electricity, and the electricity into mechanical energy again, or into heat and light. We may regard the energy which is suddenly

released upon the oxidation of the carbon in the coal as having been stored there by the sun millions of years ago, when the coal was the growing tissue of a tree. We may borrow from physics two other terms which will help us in getting the notion of the states in which energy may exist. Energy at rest — as, for example, chemical affinity (that is, the readiness of the carbon to combine with oxygen) — is called *potential* energy; energy in action, as heat, light, electricity, and motion, is called *kinetic* energy. As we have already seen, potential energy may become kinetic energy, and kinetic energy may become potential energy.

Carbohydrates, and especially fats, are capable of combining with a relatively large amount of oxygen because of the small proportion of that element in those compounds and the large proportion of carbon. Carbohydrates, chiefly glycogen, one of the many kinds of sugar in nature, are frequently made from proteins by the protoplasm in the cells and are stored in the liver cells of the higher animals, to be later transported to their muscle cells and stored in them until needed. In animals that have no liver, as an earthworm, the glycogen is stored in the cells of the lining of the body cavity and in the muscles. Fats, made either from carbohydrates or from protein food by the protoplasm, or stored directly in cells from the fatty acids absorbed through the intestine, are reserve material and are capable of supplying energy when there is need of it.

When carbohydrates and fats are oxidized the resulting compounds are carbon dioxide and water, as these foods contain only carbon, hydrogen, and oxygen. Proteins are far more complex. All proteins contain at least carbon, hydrogen, nitrogen, oxygen, sulphur, and usually, in addition, phosphorus. When they are oxidized many different compounds result. The best known of these are uric acid, carbon dioxide, and water. All these compounds are wastes.

Carbon dioxide, whether derived from carbohydrates, fats, or proteins, makes its way by the blood to the lungs, and there passes through the moist membrane and is exhaled. The carbon dioxide which is given off through the respiratory organs is produced within the living protoplasm. Lungs, gills, or other respiratory surfaces are regions where the blood supply from all parts of the body is able to get rid of its carbon dioxide. Between the entrance of the oxygen into the body and the discharge of carbon dioxide, the essential part of respiration takes place. This is the actual union of oxygen with stored food material within the protoplasm or with the protoplasm itself.

Metabolism. In the foregoing paragraphs we have shown how food material through the process of digestion and assimilation becomes made over into the substance of a living animal. The term *anabolism* covers all these changes from the time the food enters the body until it has become a part of the living animal either as living protoplasm or as stored food material. All the constructive or building-up activities of the animal body, namely, growth, repair, and storage, are the products of anabolism.

Living bodies are constantly changing. One of the most characteristic changes is the destruction of protoplasm and stored material to furnish the energy characteristic of living things. These destructive changes make up the process called *katabolism.* Respiration and the getting rid of other waste materials which have been part of the living animal (*excretion,* see page 125) are the chief manifestations of katabolism.

All the physiological and chemical changes which occur between the time when food is taken into the body and when it is used or broken down to liberate energy are collectively called *metabolism.* Metabolism is thus the sum of all the changes involved in anabolism plus those of katabolism.

Excretion. The last of the stages of metabolism is *excretion.* Excretory material is only that waste which has been formed by the breaking down of the living protoplasm and the food material stored in it. The carbon dioxide and water removed from the body in the process of respiration are excretory products. In addition various nitrogen compounds, of which urea and uric acid are the most familiar, are produced by the processes of katabolism. These wastes, dissolved in water, are collected by the blood and carried to the kidneys. Here they are separated from the blood and passed from the body as urine.

Other Wastes. The undigested food and the indigestible substances that pass through the length of the intestine are not excretory products, — a fact that has already been stated in the chapter on the grasshopper. These wastes are called *feces,* or fecal matter.

Vitamins. Until recently it was very generally thought that growth and health depended only upon sufficient quantities of food. It was discovered, however, that ample food under certain conditions may produce diseases. Sailors living on canned and dried foods became ill of a skin disease called scurvy, which disappeared when fresh fruits and vegetables were given to them. Similarly, Orientals eating practically no food but polished rice became subject to a disease called beriberi. The disease disappeared when they ate unpolished rice, containing part of the outer coating. Some of the nutritional diseases and their cures were discovered before anyone knew a scientific explanation of their causes. It is now known that these diseases are due to the lack of certain substances called *vitamins.* The vitamins are substances which must be present in the food if the animal is to be perfectly nourished (Fig. 69). If entirely deprived of vitamins for a long time, experimental animals die. No one knows exactly what vitamins are. They occur in most

fresh vegetables and fruits, the outer coating of grains, many fats, yeast, liver, milk, and eggs.

So far the vitamins have usually been named as vitamins A, B, C, D, and E. It is probable that others beyond these five may be discovered. Vitamin A is a growth-promoting vitamin. Animals fed on a diet lacking nothing but this vitamin fail to grow normally and develop diseased eyes

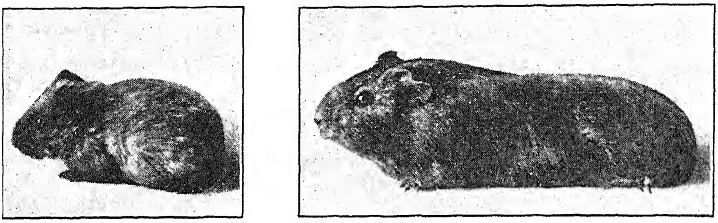


FIG. 69. These guinea pigs were from the same litter

The smaller one shows the effects of a diet deficient in vitamins. (Courtesy of Dr. Percy R. Howe, Forsyth Dental Infirmary)

and bones and have a decidedly unnourished appearance. This vitamin is found most abundantly in milk, eggs, butter, and cod-liver oil.

Vitamin B is also growth-promoting. It occurs in seeds, in yeast and egg yolks, and to a smaller extent in meat, milk, and certain vegetables and fruits. Its complete lack in the diet produces inflammation of the nerves, which may result in paralysis and death.

Vitamin C occurs abundantly in citrus fruits, tomatoes, and some other fresh fruits and vegetables. Milk, lean meat, and some dried vegetables contain vitamin C in smaller amounts. Lack of this vitamin produces the skin disease called scurvy.

Vitamin D is especially abundant in cod-liver oil. Lack of this vitamin leads to poor bone formation and a disease called rickets.

Vitamin E is one of the most recently discovered of the vitamins. Its lack in food has serious effects on the reproductive system. Animals deprived of it are either sterile or unable to produce young strong enough to live. Lettuce, cereals, meat, and egg yolks are the principal sources of this vitamin.

Methods of Reproduction. Every kind of animal has the ability of producing individuals of the same species. Only living things are capable of reproducing. Among animals there are several different ways in which reproduction may take place. Some of the simpler forms of life, which will be discussed later, undergo a separation of the entire body into two or more parts, each of which grows into a complete animal. This simple and direct method of increasing numbers is called *asexual* reproduction. Most animals have a much more complicated means of reproducing. In these, special organs are set apart chiefly for the purpose of producing young. These are the reproductive organs, such as were described for the grasshopper. They consist of the gonads, which produce the eggs and the sperm, besides ducts and various other organs and structures used in the reproductive process. Through sexual reproduction the young is produced only after the egg and sperm have united in the act of fertilization. The story of the creation of a new individual from the fertilized egg is a long one. By gradual and orderly changes, following a definite plan, the simple, fertilized egg takes on the appearance of a living creature. Some of these changes, which with others comprise the science of embryology, will be discussed in the chapter on living matter and the cell (Chapter XIII).

Glands of Internal Secretions. Within recent years much has been learned about the glands which have no ducts but empty their secretions directly into the blood. These are called the *endocrine glands* or *glands of internal secretion.*

Some of them are so small that no one has thought them important until recently. Yet several are so important that death is sure to follow their removal. The *thyroid* and *parathyroid* are located in the neck region of man and of many other vertebrates. A lack of iodine in the food causes the thyroid to swell in a disease called goiter. Years ago many operations for the removal of the thyroid in cases of goiter proved fatal. This was because other small glands of extreme importance were removed accidentally in taking out the thyroid. These are the parathyroids.

The *hypophysis* lies on the ventral side of the brain just above the roof of the mouth. This minute gland regulates growth. Giants are overgrown because of too active a hypophysis. At the upper end of each kidney there is a small gland called the *suprarenal.* Among other functions this gland controls blood pressure and in critical situations produces secretions that stimulate the body to unusual action. Within the reproductive organs, or gonads, there are important cells which have no part in forming germ cells. These so-called *interstitial cells* regulate the development of secondary sexual characters, such as the spurs of the rooster or the beard of man.

These few instances of functions give but an introduction to the understanding of these ductless glands. Though their functions are not fully understood, we do know that growth and development and the functioning of many organs are largely controlled by these glands. Even the character and personality of an individual are greatly influenced by them.

CHAPTER XIII

LIVING MATTER: PROTOPLASM AND THE CELL

> But marvel! Lump to egg doth grow,
> Puffs itself up and cracks in two.
>
> GOETHE, Faust

Protoplasm. Every living thing, whether it be a plant or an animal, is made up of a material called *protoplasm*. This living material is not a simple substance but is a mixture of various chemical compounds occuring in fairly definite proportions. Proteins, fats, sugars, starches, and various salts and minerals are dissolved and mixed as fine particles and droplets in water to comprise the chief bulk .of the living protoplasm. These are the same kinds of materials that are used as food. However, the protoplasm is not built up directly from food taken into the body. All foods must first be changed to a liquid state, and some must be changed chemically by the process of digestion. Then this liquid food material may be assimilated and become a part of the living animal. The exact composition of the protoplasm is never the same at any two instants, for it is one of the characteristics of living beings that material is constantly being destroyed and its place being taken by new substances supplied as food.

The Cell and its Structure. All but the very simplest microscopic animals and plants have their protoplasm divided into myriads of small units, each of which is called a *cell* (Fig. 70). The cell is thus the microscopic unit of structure of the animal body. The material is not uniformly distributed within the cell. There is a central body, usually

rounded in shape, which is called the *nucleus* (Fig. 70). The more fluid protoplasm around it is called *cytoplasm*. The single unit of protoplasm, the cell, has the power of carrying on all the activities of the living animal, but when many cells are united the various functions of living animals are distributed among them.

Tissues. In all animals, except the very simplest microscopic forms, the cells in different parts of the body are specialized for carrying on certain kinds of work for the whole body. Thus there is a division of labor; some cells, for example, do the moving for all the body and are termed muscle cells. When these cells of similar function are grouped together they are made up of what is known as a *tissue*. The muscle tissue, with which all are familiar in the form of a piece of lean beefsteak, is composed of countless numbers of muscle cells. The organs which have been discussed in the preceding chapters as the conspicuous structures within the body are made up of various tissues. In these tissues the cytoplasm of the individual cells becomes modified in form and structure for carrying on limited functions.

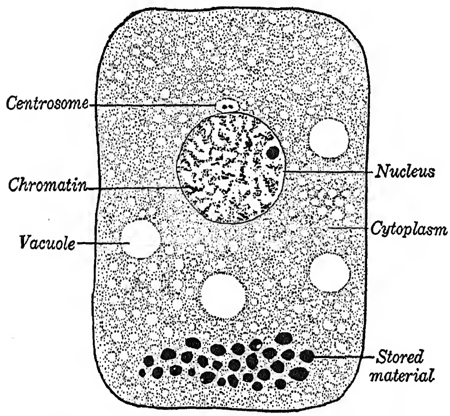


FIG. 70. Diagram of an animal cell. (Greatly magnified)

Function of the Nucleus. The nucleus seems to control the activity of the cell. Within the nucleus there is a substance that is very important because it has the power of passing from one generation to the next those features and condi-

tions which are hereditary. This nuclear material is called *chromatin* (Figs. 70, 71).

Reproduction of the Cell. There is only one way in which new cells are formed, and that is by a process called cell division. The usual method of division of a nucleus is by a very complicated procedure called *mitosis*. By an intricate series of stages the chromatin of the nucleus becomes

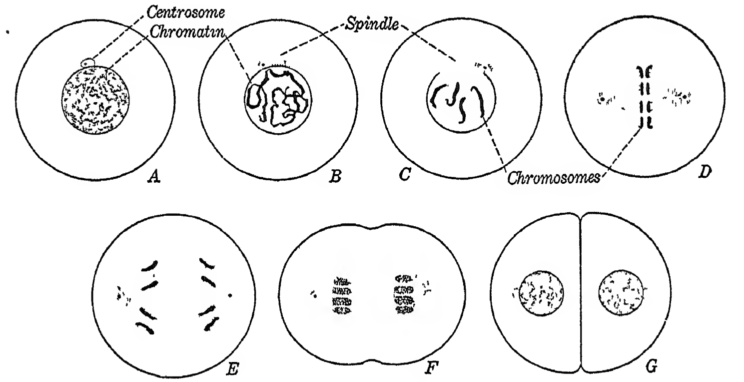


FIG. 71. Diagrams showing a cell undergoing mitosis and division

absolutely equally divided into two parts, and from each of these a new nucleus is formed. The important steps in this mitosis, or nuclear division, are outlined below.

Division of the Nucleus. The scattered granules of chromatin within a nucleus that is about ready to start division, join to form a continuous thread (Fig. 71, *B*). The thread later breaks up into small masses known as *chromosomes* (Fig. 71, *C*). While this has been going on, a small body, the *centrosome*, in the cytoplasm just outside the nucleus becomes active and forms a structure known as the *spindle* (Fig. 71, *C*). While the spindle is being formed the wall surrounding the nucleus breaks down and disappears. The chromosomes, which are thereby set free in the cytoplasm,

become attached to some of the fibers making up the spindle. For a very short time the chromosomes are arranged midway (Fig. 71, *D*) between the two ends of the spindle. While in this position each of the chromosomes splits lengthwise into two exactly equal parts. Immediately after the splitting of the chromosomes the halves of the chromosomes begin to move away from each other toward the poles of the spindle (Fig. 71, *E*). When the chromosomes become grouped around the two poles of the spindle they begin to lose their individual forms (Fig. 71, *F*). A membrane starts to form around each group of chromosomes. When these two membranes are completed there are two nuclei within the cytoplasm of the original cell (Fig. 71, *G*).

Division of the Cell. This condition is only temporary, for ordinarily mitosis is followed by a division of the cytoplasm. The mass of the cytoplasm begins to constrict about its middle (Fig. 71, *F*). As this constriction deepens, the original mass of cytoplasm is pinched into two pieces, each of which surrounds a nucleus (Fig. 71, *G*). By this means two new cells take the place of the one cell with which the description started. Each of the two new cells contains but half the material from the mother cell. But it is one of the characteristics of living protoplasm that it can take material furnished to it as food and build up more protoplasm in the process termed growth. By growth the two small cells increase in size until they are as large as the mother cell which produced them.

Numbers of Chromosomes. As mentioned in an earlier paragraph the chromatin material is very important in the nucleus. It seems that the whole elaborate process of mitosis has as its chief aim the exact division of this material. When the chromatin forms into chromosomes there is always a fixed number of chromosomes typical for each species of animal. In some animals there are only two, while others

have different numbers, which sometimes reach more than a hundred in every cell. Each cell in the body tissues of a man contains forty-eight chromosomes.

Protoplasm and Life. Though protoplasm is made up of well-known substances it can be produced only by protoplasm. Many scientists have tried to mix materials together to produce protoplasm. Although they can produce something which looks like protoplasm, no experiment has ever produced living protoplasm; in fact, it is very doubtful if living protoplasm can ever be formed artificially.

Mitosis during Sexual Reproduction. In the chapter dealing with life processes mention was made of the fact that reproduction is usually through specialized products called germ cells. In the formation of the young from the germ cells we find one of the most conspicuous instances of cell division. The changes which lead up to the multiplication of cells in the embryo will be described here.

Germ Cells. Germ cells produced by females are relatively large cells containing stored yolk to be used as food material by the developing young (Fig. 72, *A*). The cells produced by the males are very small cells (Fig. 72, *B*, *sperm cell*), capable of locomotion, called *spermatozoa* or *sperm*. Neither of these minute bodies in any measure resembles the animal which produced it. Yet after a long series of steps, or stages, an egg and a sperm unite and finally form an individual like the animals which produced them.

Maturation and Fertilization. The act whereby an egg and a sperm are united to start the formation of a new individual is called *fertilization* (Fig. 72, *B–D*). Before this act can take place both egg and sperm must have gone through a period of preparation, which is called *maturation*. During maturation the most important changes take place in the nuclei of the germ cells. It will be remembered (p. 131) that the nucleus contains a substance called chromatin, and

that this chromatin is the substance by which hereditary characters are passed from one generation to the next. After maturation each germ cell has but one half the amount of chromatin which it possessed before maturation started. This reduction of the chromatin prepares the germ cells for fertilization. In consequence, when a mature egg and mature sperm join in fertilization each brings but one half its original amount of chromatin. The fertilized egg therefore contains the usual or normal supply of chromatin, one half of which was in the mature egg before fertilization and the other half was added by the sperm (Fig. 72, *E*). At the end of fertilization the sperm and egg have completely joined to form a single cell having a single nucleus. It is from this single cell, the fertilized egg, that the new individual has its origin.

Cleavage. By mitosis the nucleus of the fertilized egg divides to form two nuclei and from the one cell two complete cells are produced (Fig. 73, *B*), but they remain attached to one another. This multiplication of cells from the fertilized egg is called *cleavage.* After two cells have been formed, each undergoes mitosis and cleavage, so that from two cells four are produced (Fig. 73, *C*). This cleavage process continues in all the higher animals until the original fertilized egg has formed a large number of cells.

Blastula. Even as early as the eight-cell stage in the embryo, or developing young, the cells in many species arrange themselves in such a manner as to have a small cavity in the interior of the group. Such a stage where the cleavage cells are arranged as a single layer of cells surrounding a cavity is called a *blastula* (Fig. 73, *E*).

Gastrula. In later development one region of the blastula wall begins to push inward just as a hollow rubber ball may be indented (Fig. 73, *F*). As this ingrown region deepens the cells which were in a single layer during the blastula stage become recognizable as an outer-surface covering, or

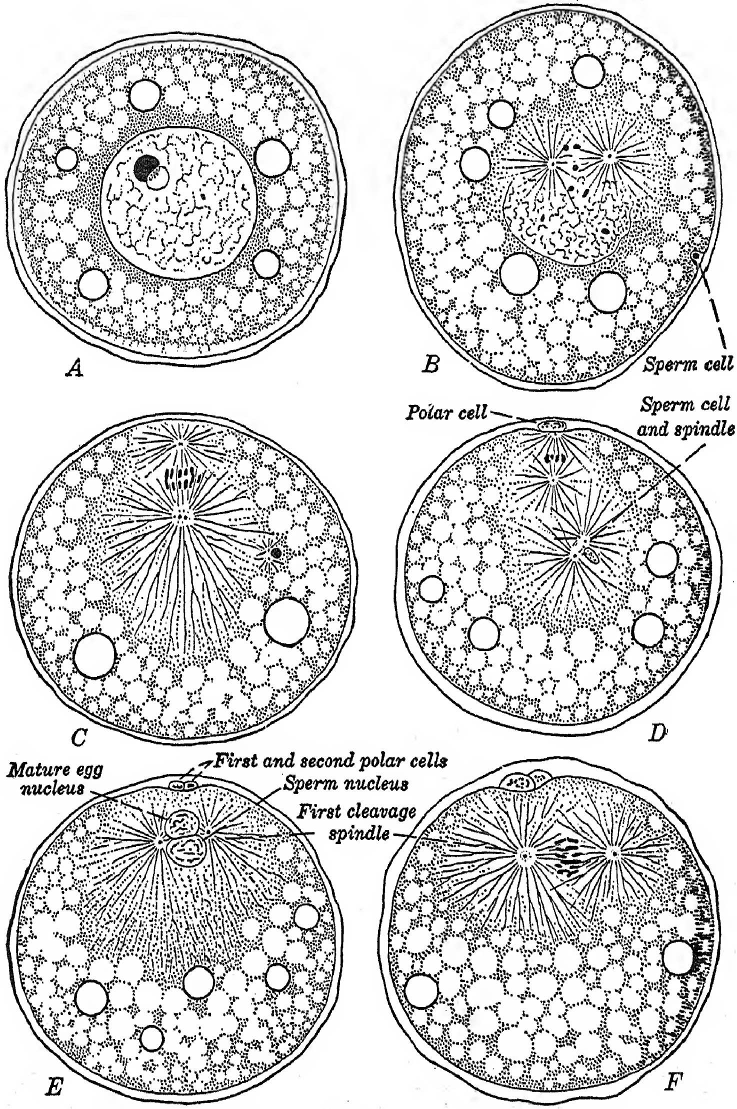


FIG. 72. Maturation and fertilization in the egg of a worm, *Nereis*

After Wilson

ectoderm, and a layer lining the inturned region, called the *endoderm.* This stage, when the embryo consists of two layers of cells, is called a *gastrula.*

Later Development. Between the ectoderm and endoderm a third layer, or group, of cells forms (Fig. 73, *G*). These are called the *mesoderm.* From these three layers of cells the fully formed animal grows. The cells which differed

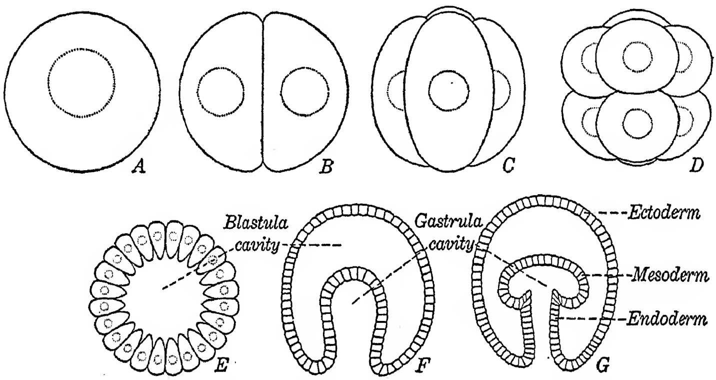


FIG. 73. Cleavage of the egg and early development of the starfish. (Enlarged diagrams)

A, egg before development starts; *B,* two cells resulting from the division ot the fertilized egg; *C,* four-cell stage; *D,* eight-cell stage; *E,* section through the blastula stage; *F,* section through gastrula stage; *G,* a later gastrula, showing how mesoderm is formed

little from one another except in size become specialized for various work. This specialization began with the formation of the gastrula, for the cells of the endoderm form a sac, which in some animals serves as a stomach, or later develops into a digestive system. From the outer layer, or ectoderm, the skin and the nervous system develop. The lining of the alimentary canal comes from the endoderm. The most of the rest of the body is formed from mesoderm. This includes the muscles, excretory system, circulatory system, and reproductive organs.

CHAPTER XIV

THE SPIDERS AND ALLIES: ARACHNIDA

A noiseless, patient spider,
I marked where, on a little promontory, it stood isolated;
Marked how, to explore the vacant, vast surrounding,
It launched forth filament, filament, filament out of itself;
Ever unreaching them — ever tirelessly speeding them.

WALT WHITMAN

Spiders. Spiders have several of the anterior somites joined into a single mass, the head-thorax, or *cephalothorax* (Fig. 74), followed by the *abdomen*. The cephalothorax bears six pairs of appendages, — two pairs of the nature of jaws and four pairs of *walking legs*. The *cheliceræ*, the first pair of jaws, are appendages composed of two segments, of which the terminal segment is sharp pointed and hollow, for the passage of a poisonous secretion from a gland placed partly in the head and partly in the basal segment. The second pair of jaws, or *pedipalps*, bear jointed feelers, used for handling food. On the front of the head are eight *simple eyes*; compound eyes and antennæ are wanting.

Two little slits on the under side of the abdomen open into the *breathing organs*, or *lung books*, which consist of a pair of sacs containing a number of thin plates, like the leaves of a book. Between the two slits are the external openings of the *reproductive organs*. At the end of the body are three pairs of *spinnerets*, consisting of a number of little tubes leading from glands in the abdomen, which secrete a viscous fluid that hardens into silk on exposure to the air. Two *tracheæ* (Fig. 74), which give off branches to different parts of the abdomen, open just in front of the spinnerets.

Many spiders build circular webs of silk, in which they capture insects to suck their blood. A common species of garden spider (*Miran'da auran'tia*) is shown in Fig. 75. The spider first spins a line across the space where the web is to be and then attaches near its center other threads, which it carries to different points, making the radiating foundation lines of the web. These lines are all dry and inelastic. Concentric spiral lines of an adhesive nature are then added, the hind legs being used to place the threads. An oval cover of silk is spun in the center. Beneath this, or in a folded leaf at the side, the spider lurks in watch for its prey. A zigzag band of white silk crossing the center is usually added to strengthen the web. When an insect is captured the spider rushes out, and if there is any danger of the escape of the prey it is deftly wound with more silk till its struggles have ceased. If it proves to be a wasp or other dangerous captive, or if it is too big to be safely managed, it is often assisted to escape by the spider's cutting the web, which is then repaired for another victim.

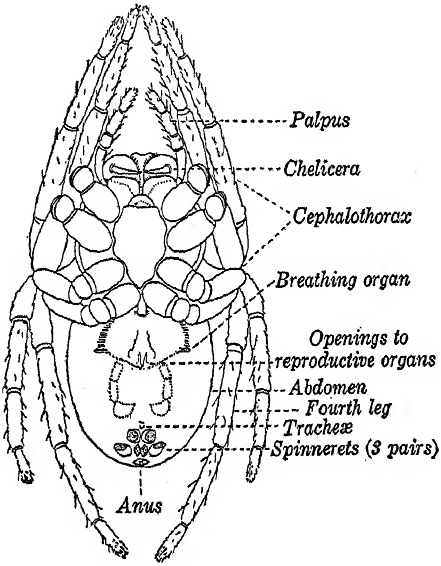


FIG. 74. External anatomy of a spider, *Epeira vulgaris*. (Enlarged)
After Emerton

Like the click beetles and many others of the Coleoptera, this spider when alarmed has the habit of dropping to the

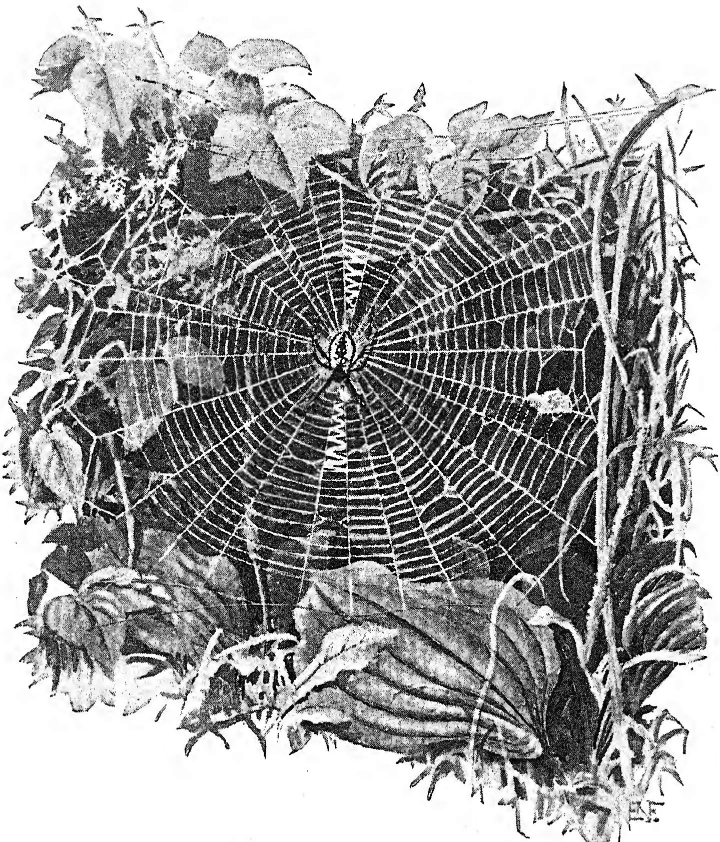


FIG. 75. Garden spider and web. (Reduced)

ground as if dead. It spins a thread of silk as it drops; when the danger is over, it is able by this means to return to the web.

The eggs of the garden spider are laid in the autumn in a sac of silk (Fig. 76), which may contain from five hundred to two thousand eggs. These eggs hatch early in the winter, and the young live in the case through the cold weather.

By spring a comparatively small number of spiders emerge; for they are cannibals and the survivors have lived only because they had brothers and sisters to eat, no other food having been provided for them. By successive molts, without marked metamorphosis, they reach their adult size.

The dark-colored, hairy spiders (*Lyco'sa*) found under sticks and stones are called wolf spiders. They usually build tubular tunnels in the ground, which they line with silk. These do not make a web to capture their prey, but spring upon it as they run about in search of food. The females may often be seen dragging after them the large gray ball which contains, at first, their eggs, and afterwards the young. After a certain time the young leave the silken case, and for some time longer run about over the body of the mother.

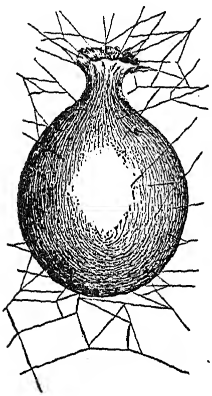


FIG. 76. Egg case of garden spider. (Natural size)
After Wilder

These spiders are often called tarantulas, but that name should be restricted to the large hairy spiders of the warm parts of the world. The true tarantulas (Fig. 77) can be distinguished from all other spiders by the fact that the terminal segment of the cheliceræ works vertically instead of horizontally. Tarantulas are universally dreaded in the countries where they grow to be of large size, and they are believed to be very poisonous. The ability of any spider to pierce the human skin depends, of course, on its size and the strength of its jaws; the effect produced by the bite depends not only on the amount of poison injected into the wound but also on the age and mental and physical condition of the person bitten. Though many stories of death by tarantula bites have been told, most of them are clearly

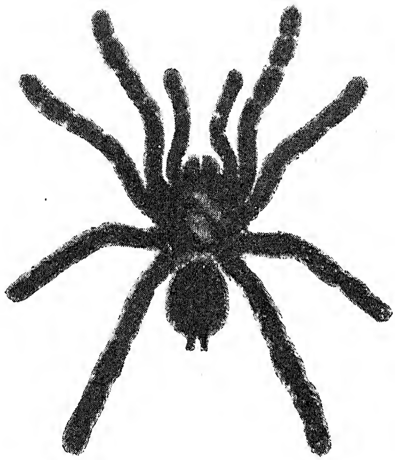


FIG. 77. A tarantula

untrue. What usually happens is that persons bitten by them suffer only temporary pain and swelling, something like that which follows the sting of a bee.

Among the most interesting of the tarantula family are the trapdoor spiders of the Western and Southern states, and of southern Europe. They build burrows, which they line with silk, and provide with a lid lined with silk, attached by one edge to the mouth of the burrow. A European species builds a nest with a side tube (Fig. 78), into which it can retreat in time of danger, closing a door at the entrance of this tube.

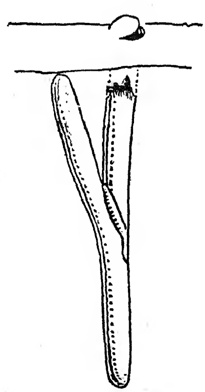


FIG. 78. Burrow of a trapdoor spider, showing side tube

After Emerton

Harvestmen. The long-legged harvestmen, or daddy-long-legs (*Liobu'num*, Fig. 79), are allied to the spiders. They can be recognized by the eight extremely long legs, which are thus developed as organs of touch, as well as for walking. They are familiar creatures, found in damp and shady places. They feed on small insects, especially aphids.

Mites and Ticks. The mites and ticks are related to the harvestmen and to spiders. They show less segmentation of the body than the preceding groups (Fig. 80). They are small, oval, eight-

legged forms. The mouth parts are more or less united to form a beak for sucking blood. They live as parasites.

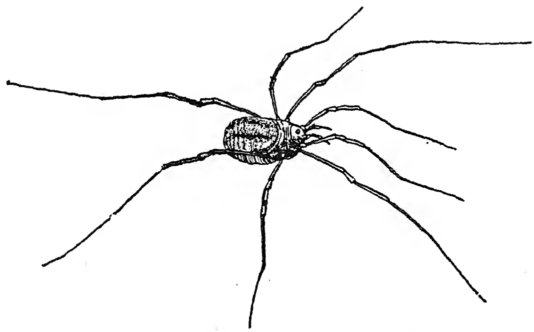
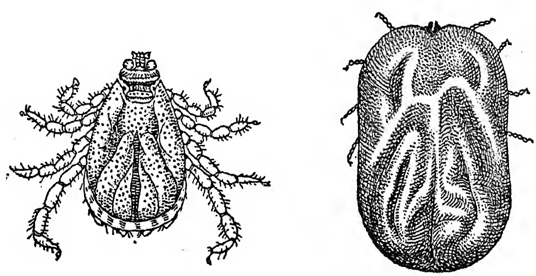


FIG. 79. Harvestman. (Natural size)

Ticks in Relation to Disease. Almost everyone who spends any time in the woods has had the experience of finding a small brown creature firmly attached to his skin, rapidly



A *B*

FIG. 80. Cattle tick. (Enlarged)

A, male tick; *B*, female filled with blood from host. (From the United States Department of Agriculture)

gorging itself with blood. This is the common wood tick. The species found in the eastern part of the United States is practically harmless. A closely related species (*Dermacen'tor venus'tus*) in the northwest of our country carries

an organism which produces a very serious human disease called Rocky Mountain spotted fever. In the Bitterroot valley of Montana more than 75 per cent of the cases end in death. Texas fever, a disease of cattle in the southern part of the United States, is due to a parasite also carried by the bite of a tick (*Margar'opus annula'tus,* Fig. 80). The disease carried by this tick has resulted in cattle losses in the Southern states amounting to millions of dollars.

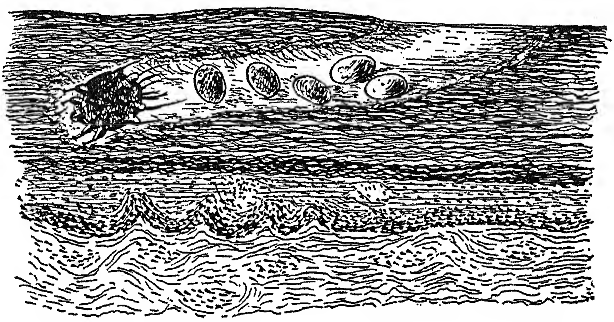


FIG. 81. Itch mites burrowing in the skin of man. (Enlarged)[1]

Mites as Parasites. There are many species of these minute, almost microscopic animals. Some of them are parasites of man. The harvest mites, or chiggers, are common in woodland pastures in midsummer. Young harvest mites have the habit of burrowing into the skin of man, where they set up intense irritation and severe itching. The peculiar part of it is that these mites which attack man commit suicide by doing so. Only the ones which become attached as parasites on the bodies of insects reach maturity. The itch mites (Fig. 81) are another type of almost microscopic creatures which burrow beneath the skin and lay their eggs in these burrows. One species (*Sarcop'tes scab'iei*) produces

[1] Reprinted by permission from *Handbook of Medical Entomology,* by W. A. Riley and O. A. Johannsen, published by The Comstock Publishing Co.

a skin disease of man commonly called "the itch." Other species attack various mammals. Mange, a common skin disease of dogs, is produced by mites burrowing in the skin.

Scorpions. The scorpions have the body plainly segmented. In the common scorpion (*Bu'thus*, Fig. 82), found under sticks in our Southern states, the pedipalps are greatly elongated, making a formidable-looking pair of claws. The abdomen is provided with a sting at its extremity. This is not operated like the sting of a bee or wasp but is a lance-like organ which is thrust into the enemy by the whip-like motion of the whole tail. The whip scorpion (*Thelyph'onus*), also found in similar situations in the South, is another formidable-looking creature, with immensely developed pedipalps. These are used to pull open decaying wood in search of small insects, which form its food. Its appearance accounts for the dread it inspires, but there is no evidence to show that it is harmful to man.

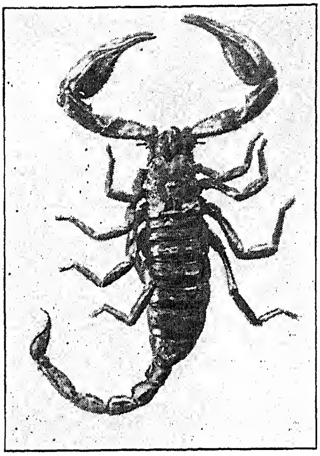


FIG. 82. Photograph of scorpion

American Museum of Natural History

Definition of Arachnida. The name "Arach'nida" is applied to the spiders, scorpions, mites, and ticks, all of which are segmented animals with jointed appendages but lacking antennæ. There are normally four pairs of legs, though the young stages commonly have but three pairs. The lack of antennæ and the greater number of legs are the two most conspicuous points of difference between the Arachnida and Hexapoda.

CHAPTER XV

THE CRAYFISH

All night the crawfish deepens out her wells,
As shows the clay that freshly curbs them round.

J. P. Irvine, Summer Drought

Habitat and Distribution. Crayfishes, also called crawfishes, are found in bodies of fresh water on every continent except Africa, and on many of the large islands. All the crayfishes of the United States east of the Rocky Mountains belong to the single genus *Cam'barus*. On the Pacific coast the crayfishes are slightly different. All of them belong to the genus *As'tacus*. An eastern American species (*Cam'barus limo'sus*) is used as an example in this chapter. In structure all members of the genus *Cambarus* are so nearly identical that for a general laboratory study any species available is entirely satisfactory.

External Plan of Structure. The body, except for the ventral surface of the abdomen, is covered with a thick wall, formed, like the covering of insects, from the hardening of a secretion of the outer layer of the skin. Unlike the insects, this protecting sheath is filled with carbonate of lime. The body is divided into a *cephalothorax* and *abdomen* (Fig. 83), as in the arachnids. There are no indications on the dorsal surface of separate somites in the cephalothorax, but on the ventral surface transverse grooves and paired appendages indicate a division into thirteen *somites*. The abdomen (Fig. 83) plainly consists of seven somites, of which the first six bear jointed appendages. The external plan upon which the crayfish is formed is similar to that of the insects

and arachnids; that is, a series of somites placed one after the other, with all appendages jointed.

The Cephalothorax. The shell covering the dorsal and lateral surfaces of the anterior region of the body is distinct from the hard parts elsewhere on the body, and is termed the *carapace*. At the anterior dorsal end of the carapace there is a prominent beak, or *rostrum*, beneath which, on either side, extends an *eye*, borne on a stalk. Study of the living crayfish enables one to see how well the rostrum and the *squame*, mentioned below, protect the stalked movable eye. The eye is compound; the manner in which the image is formed is practically the same as in the insects. Crayfishes have no simple eyes.

The cephalothorax bears at its anterior end six slender, many-jointed feelers, the short ones called *antennules* (Fig. 83), the long ones, *antennæ*. The four antennules are really the four branches of a single pair of appendages coming from a short stem which is attached to the body. On the upper surface of one of the segments of this stem is a small hole surrounded by a number of bristles. The hole opens into a cavity which contains several small grains of sand placed there by the crayfish itself after every molt (the process of molting is explained in Chapter XVI). This organ, with its nerve connections, constitutes the "ear" of the crayfish (Fig. 83), the chief function of which is to help the animal to balance itself during locomotion. The technical name *otocyst* is given to it. The antennæ are the inner branches of a pair of double-branched appendages. The outer branch of each is short, flat, and triangular, and lies just below the eyes, where it serves a protective function. It is called the *squame*. On the lower, or basal, segment of the stem of this pair of appendages is a small, hard, round swelling, or *papilla* (Fig. 84, II, *1*), on which is the opening from the "kidney," or *green gland*, shown in broken outline in Fig. 83.

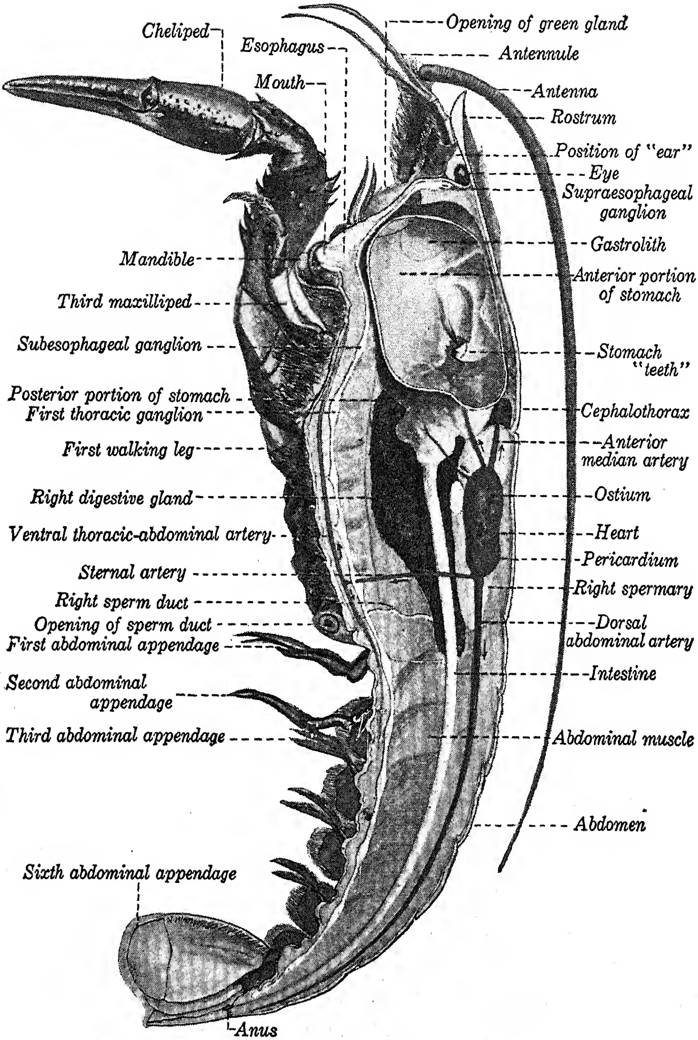


FIG. 83. Dissection of crayfish. (Slightly enlarged)

About the mouth are six pairs of appendages. The first, the hard *mandibles* (Fig. 83), are adapted to crushing into smaller bits the food seized by the large claws. Each mandible bears a short *palpus* (Fig. 84, III, *2*). Next in the series are the *first* and *second maxillæ* (Fig. 84, IV, V) and the *first, second,* and *third maxillipeds* (Fig. 84, VI, VII, VIII). The maxillipeds help to hold the food in place at the mouth; the maxillæ also assist in this, and probably, with the wall of the mouth cavity, are the seat of the sense of taste. The second pair of maxillæ also act as "gill-bailers" (Fig. 84, V, *3–4*; Fig. 85), which, by their motion, help to maintain a current of water in the *gill chamber,* thus providing oxygen for respiration. The separation between head and thorax is understood to come between the second maxillæ and the first maxillipeds, thus making five pairs of appendages in the head region.

After the maxillipeds the next thoracic appendages are the large claws, or *chelipeds* (Fig. 83), composed of seven segments, of which the last two from the body, or distal two, are modified to form a nipper, with which the animal captures and holds even rapidly swimming fishes. The remaining thoracic appendages are the four pairs of *walking legs* (Fig. 83; Fig. 84, XI, XII), also composed of seven segments, the first two pairs with nippers at their ends, and the last two pairs without nippers. The three pairs of maxillipeds, the one pair of chelipeds, and the four pairs of walking legs constitute the eight pairs of appendages of the thorax.

The Abdomen. There are six pairs of appendages on the abdomen. The first abdominal appendages of the female are small, single, and thread-like; in the male (Fig. 83) they are long and rigid, differing considerably from all the others except the second pair. The second abdominal appendage in the female is like the third. The third, fourth, and fifth

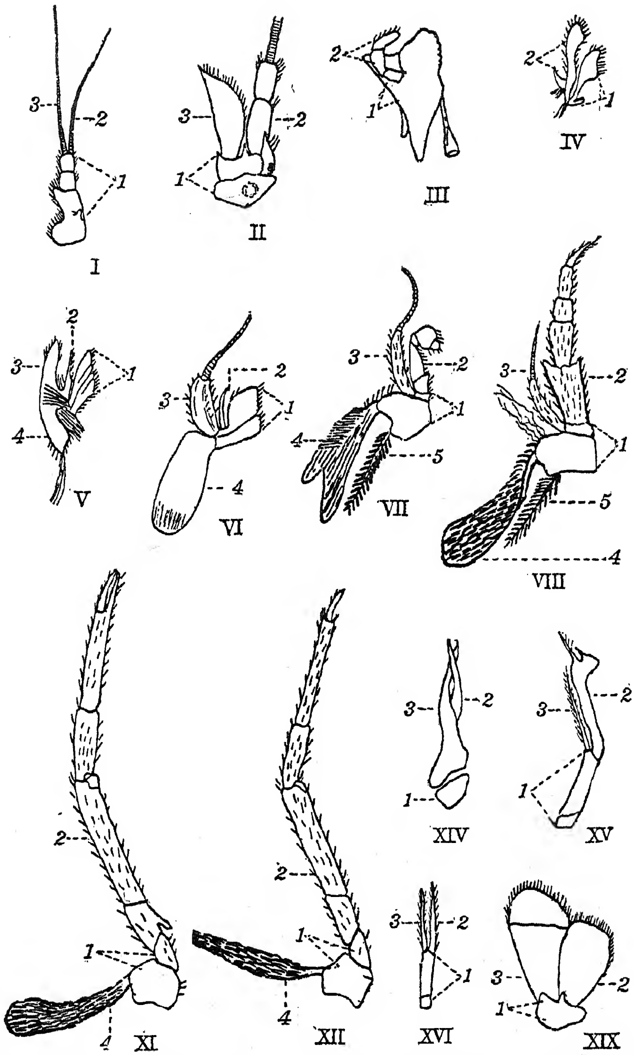


FIG. 84. Appendages of the crayfish (*Cambarus*), from the left side. (Natural size)

1, protopodite; *2*, endopodite; *3*, exopodite; *4*, epipodite with gill filaments; *5*, gill with gill filaments. (I, II, III, etc., stand for the number of the somite in the animal's body)

pairs, called *swimmerets,* are alike in both sexes. The pair of appendages of the sixth somite are made up of broad, flat branches jointed to a short, thick stem. With the last somite, called the *telson* (which is without appendages), they form a strong tail fin. By being doubled underneath it is capable of striking hard blows against the water and forcing the crayfish suddenly backward. A basal stem with two branches is seen in all the abdominal appendages except in the first pair of the female.

Homology. A stem and two branches are apparent in several appendages. This is important enough to deserve further discussion. The simplest condition of the branched appendage is seen in the third, fourth, and fifth abdominal appendages (Fig. 84, XVI). If the branches are spread slightly, the form resembles the capital letter Y. If we take a swimmeret as a model, the stem, which is termed the *protopodite* (Fig. 84, XVI, *1*), is seen to be made up of a short basal segment, the *coxopodite,* and a long segment, the *basipodite.* Of the two branches, the one nearer the median line of the body is the *endopodite* (Fig. 84, XVI, *2*); the outer is the *exopodite* (Fig. 84, XVI, *3*). Wherever in the series of appendages we find a stem and two branches, the protopodite corresponds to the protopodite of all the other appendages of the series,— and so with the endopodites and the exopodites.

All the remaining appendages of the crayfish are constructed on the same general plan as the swimmerets; but the original plan, in being modified for different functions, has frequently become obscured. Thus in the walking legs we have no evidence of a two-branched condition. In the very early stages of development the young crayfish before hatching has legs that bear two branches, but one of these disappears entirely before the young is hatched. In the case of the lobster the young animal (Fig. 86) still has the two-

branched legs after hatching and only later in development loses one branch. The remaining appendages are too complicated to be studied here in detail; but the early stages in the embryo show that all of them, whatever their adult structure, begin their existence as two-branched appendages similar to the swimmerets.

When two or more organs or structures are constructed upon the same plan and develop in the young in the same

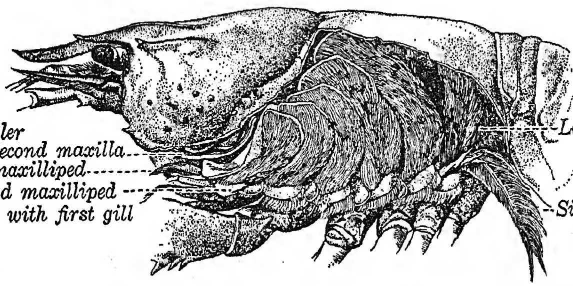


FIG. 85. Gill chamber and gills of crayfish. (Slightly enlarged)

way, they are said to be *homologous*. Since all the appendages of the crayfish are of the two-branched type, they furnish a good example of *homology*.

The Digestive System. The *mouth* (Fig. 83) of the crayfish is located between the two mandibles. Reference to Fig. 83 will give an idea of the length of the *esophagus* and the position and relative size of the *stomach*. The latter has two more or less clearly marked regions, — the anterior, enlarged region and the posterior, funnel-shaped space. As the food passes into the anterior portion the unbroken bits are caught between the grinding surfaces of three hard processes extending from the stomach wall. These three "teeth" — one in the median dorsal line and two at the sides — together constitute the "gastric mill." Muscles attached to them and to the inner surface of the carapace, by contract-

ing, perform the operation of grinding. The posterior part of the stomach is filled with slender filaments which extend from the wall out into the cavity. These filaments prevent the unbroken particles of food from passing through into the intestine, allowing only the thoroughly ground-up food to do so. Absorption does not occur in either division of the stomach but in the *intestinc,* which extends straight from the stomach to the ventral surface of the telson. A pair of *digestive glands* lie one on either side of the stomach and intestine. They open by tubes into the posterior division of the stomach and have the combined functions of digesting food and absorbing some of the products of digestion.

The Circulatory, Respiratory, and Excretory Systems. The *heart* is a muscular organ lying beneath the dorsal body wall posterior to the stomach. The blood finds its way into the heart through three pairs of openings furnished with *valves* to prevent the escape of blood. When the heart contracts the blood flows both forward and backward at the same time through the tubes called *arteries.* Five arteries pass forward to the organs in the front part of the body while two are directed backward to supply blood for the posterior region. These arteries branch into many smaller vessels with open ends. From the open ends the blood flows into spaces called *sinuses* surrounding the internal organs of the body. All the sinuses connect with a still larger, median cavity, the *ventral sinus,* lying along the ventral wall of the thorax and abdomen. Branches from the median ventral sinus extend out into the gills. The blood is carried back to the base of the gills by another set of channels parallel to the set entering the gills. Finally the blood reaches the *pericardial sinus,* in which the heart lies. The delicate plume-like *gills* (Fig. 85) are attached to or near the basal joints of the thoracic appendages. On each side of the body they extend dorsally into partially

closed chambers bounded by the body wall on the inside and the carapace on the outside. Since the crayfish frequently journeys from pond to pond in dry seasons, the gills are thus protected from sudden drying. Water is drawn into and is forced out of this gill cavity by the *gill-bailers* on the second maxillæ (Fig. 84, V, *3–4*; Fig. 85). The blood flowing into the gills from the ventral sinus gives up its carbon dioxide waste and receives oxygen from the water.

The *green glands* are prominent organs (Fig. 83) in the ventral region of the body cavity in the head. A large artery carries blood to them, and nitrogenous waste matter is separated by them from the blood and is discharged from the opening on the basal segment of each antenna.

The Nervous System. The central nervous system of the crayfish is much like that described for the grasshopper. A double cord extends the length of the body. On this cord there are seven enlargements, or ganglia, in the cephalothorax and six in the abdomen. The "brain," or *supraesophageal ganglion,* is a large mass of nerve tissue (Fig. 83). Pairs of *nerves* may be traced from the brain to the eyes, the antennæ, and the antennules. Two slender cords, similar to those described for the grasshopper, extend from the brain, encircle the esophagus, and join the *subesophageal ganglion* posterior to the mouth. This ganglion sends off the nerves to some of the head somites and to some of the thoracic somites. There are five other ganglia in the thorax joined to each other (Fig. 83) and to the six ganglia in the abdomen by the double nerve cord which is a continuation of the cords that encircle the esophagus.

The Muscular System. The muscles of the abdomen are arranged in a very complicated fashion and are capable of powerful action. The compact muscle bundles of the abdomen, or "tail," of the crayfish and also of the shrimp are the chief parts used by man as food. In all parts of the body

the muscle bundles are attached to the inner surface of the exoskeleton. This is just the opposite of the relations of muscles to skeleton in our own bodies.

The Reproductive System. The three-lobed organ which produces the germ cells lies just beneath the heart. In the male this is a *spermary,* or testis, while in the female it is called an *ovary.* In both sexes a pair of ducts lead from the reproductive organ (or *gonad*) to a pair of openings on the bases of certain walking legs. These *sperm ducts* of the male open on the basal segment of either fourth walking leg. In the female the *oviducts* lead to similar openings on the second walking legs.

Development. *Cambarus limosus* lays its eggs in the spring. Most species of crayfishes lay their eggs then. The principal burrowing species, *Cambarus diog'enes,* lays its eggs in April and they hatch in May, while a river species, *Cambarus immu'nis,* lays its eggs in the fall and they hatch in the following spring. When the egg-laying season arrives the male deposits spermatozoa in a shallow cup called the *annulus* on the ventral surface of the female between the fourth pair of legs. The mass of spermatozoa stays in the annulus till the female lays her eggs. It is not certain how long the spermatozoa lie there before the eggs are laid. However, when the eggs are discharged from the oviducts they pass back over the mass of spermatozoa. Fertilization is accomplished when a spermatozoon enters an egg. The fertilized eggs are fastened to the swimmerets by a glutinous substance. There the embryos develop, and the young, when they hatch, remain clinging to the female's swimmerets by their chelipeds. The young crayfishes are not set free until they are able to care for themselves.

Relation to Environment. Crayfishes live in a great variety of places. They are fresh-water animals. As a rule they crawl on the bottom of rivers, brooks, and ponds, conceal-

ing themselves in crevices or under protecting pieces of rock or submerged logs. Several species make burrows in the soft earth of meadows. The most widely distributed of these is *Cambarus diogenes*. Species which live in ponds that are likely to dry up in the summer, and also a few that live in rivers, leave the water in summer and burrow into the earth until they come to water. At the bottom of their burrows, sometimes three feet from the surface, they dig out a flask-shaped enlargement and stay in it or near it till the next spring. The chimneys made at the top of the "wells" referred to in the quotation at the beginning of the chapter are made by the burrowing crayfish merely as an incident in getting rid of the mud brought from below. Sometimes crayfishes stop up their burrows completely. In that case they probably remain in a dormant condition without food till spring returns. In the bed of a pond or river where jutting stones abound crayfishes rest with the abdomen doubled beneath them and the head toward the open. Boys often lure them from their hiding places with a piece of meat tied to the end of a weighted string. The animal invariably seizes the meat in a cheliped and usually can be drawn to the surface before it has time to "think" the matter over and let go.

The distribution of crayfishes is directly related to their power of adapting themselves to conditions of considerable variability. If a certain definite degree of temperature or of clearness of water were required, they would be restricted to a very limited area, and, indeed, it would be difficult for them to maintain themselves at all.

A striking example of adaptation to an unusual environment is found in the cave-dwelling crayfish, *Cambarus pellu'cidus*. Professor Eigenmann, Mr. W. P. Hay, and others have explored the caves of Indiana and Kentucky for the purpose of studying the animals of their subterranean

rivers. The blind crayfish has small and abortive eyes, but its sense of touch is developed to a marvelous degree of delicacy. Mr. Hay says that although the crayfishes may be resting quietly on the bottom of a rivulet, it is impossible to capture them with a net. They feel the jar in the water and dart backward with great accuracy to a protecting rock. In general appearance the blind crayfish differs from others chiefly in having an exoskeleton which is so clear that one may see the animal's stomach as a blue mass within, and in being provided with antennæ longer than the body.

Crayfishes are eaten by fish large enough to swallow them, and they in turn catch small fish with great facility, and also insect larvæ, snails, tadpoles, and even frogs. They have been known to prey upon each other, and also to eat both dead and living plant and animal food. They seem to be omnivorous.

In America crayfishes seem to be used as food chiefly by the French portion of our population. Possibly the rapid depletion of the lobster fisheries may cause people generally to turn to the lobster's nearest edible relative. In France the crayfish industry is quite extensive, there being many farms on which crayfishes are raised for the market.

CHAPTER XVI

THE JOINTED-FOOT ANIMALS: ARTHROPODA

The Shelly Crawlers each returning year
Cast off their shells and new-made Armour wear.

OPPIAN, Halieutica

THE ALLIES OF THE CRAYFISH: CRUSTACEA

The Lobster. Except for the considerable difference in size, and the slight differences in the shape of the body, the number of gills, and the structure of abdominal appendages, the description of the adult crayfish would serve for an account of the structure of our common species of American lobster, *Hom'arus america'nus*. The lobster is found in greatest numbers along the coast of Maine and of the Canadian maritime provinces. Toward the south the number gradually decreases to the Delaware breakwater, beyond which they are very rare. In their days of greatest abundance they grew to be about sixty centimeters (two feet) in length, weighing twenty-five pounds, but with the increase in the activity of the lobster-fishing industry they are now rarely to be found weighing over two pounds.

The lobster lives on the bottom. It is protectively colored, but it does not depend wholly upon that condition for escaping the notice of its enemies. In shallow waters lobsters are known to conceal themselves beneath masses of brown seaweed in pits and holes, and also to find safe retreat beneath jutting ledges of rock, where they rest with the abdomen doubled beneath, ready to dart out and seize passing prey in their claws. We have no way of knowing the exact habits of the animal when at its greatest depth

(a hundred fathoms), but since its enemies are probably quite as persistent there as in the shallow water, every means of defense is likely to be employed to the utmost.

The lobster is capable of swimming with great rapidity by suddenly doubling its flexible, muscular abdomen beneath and shooting backward through the water. This form of locomotion does not appear to be depended on except to enable it to escape from impending danger. Its usual mode of progression is by walking on the tips of the last four pairs of legs, the chelipeds being extended anteriorly, apparently to expose as little of its bulk to the water as possible. Experiments indicate that lobsters do not travel great distances. Hence if all the lobsters in a certain bay and vicinity are caught, the chances are against that region recovering its lost supply. Laws have been passed by the individual states to regulate the lobster fisheries. The chief attempts at avoiding extermination have been the prohibition of the sale of lobsters under a certain length and the protection of females carrying eggs. Hatcheries have also been established for rearing the young to the stage where they leave the surface of the water and begin to live on the floor of the ocean. All these attempts have been only partially successful and have not really solved the problem of materially increasing the numbers.

Molting in the lobster, as in some other animals with a hard exoskeleton, is an extremely important and critical event. The number of molts an individual lobster may have depends, in a great measure, upon the abundance of its food. Males molt more frequently than females; hence the largest lobsters are always males. Very young lobsters molt more frequently than those of the size we find in the market. During the process of molting it sometimes happens that an appendage is broken off. In the ordinary course of its life, also, the lobster may lose a claw or an

antenna. It is regenerated in two or three molts after the accident. The crayfish and many other animals have the same power.

The female lobster lays her eggs usually during the summer months. The eggs remain attached to the swimmerets until the next spring, when the embryos hatch. The larval lobster (Fig. 86) immediately floats to the surface, and for several weeks swims about there. Its length at first is about eight millimeters (one third of an inch). In general appearance it slightly resembles the adult lobster. The large thoracic appendages are not leg-like but are two-branched, and the abdomen has no appendages. After the sixth molt the lobster is about two thirds of an inch long. The outer branches of the legs have disappeared and the young lobster has gained abdominal appendages. It is now nearly like the adult in all respects. At about this time the young leaves the surface, goes to the bottom, and makes its way to well-protected places near the shore.

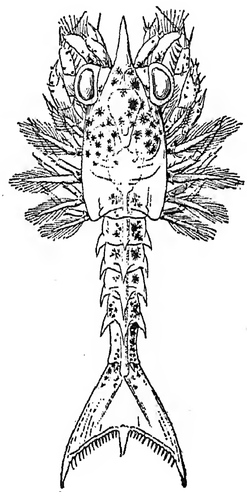


FIG. 86. First larval stage of American lobster. (×7)

After Herrick

The commercial value of the lobster is very great. As an article of human food it is fast becoming a luxury. Lobsters rank next to codfish in importance in the New England fisheries. In 1924 close to ten million pounds were marketed with a value of over three million dollars. Most of the lobsters for market are caught in traps commonly called lobster pots. Bait is placed inside the trap, and when the lobster crawls through a small opening in the funnel-shaped entrance it is unable to discover the exit.

The Common Prawn. The prawn (*Palæmone'tes vulga'ris*, frontispiece), is found abundantly among seaweeds near shore in sea water and also in brackish and almost fresh water. It is a good example of a pelagic, or surface-inhabiting, animal of considerable size, which is so nearly transparent that it may be overlooked unless it moves. The prawn, or, as it is frequently called, the shrimp, is about two inches long and resembles in general form the lobster or the crayfish. The body is, however, more compressed (flattened from side to side) and more strongly arched from head to tail. The carapace is thin but tough and leathery, and covered with many reddish-brown dots. It is so transparent that the stomach and intestine can be seen clearly while the animal is at rest.

The Edible Shrimp. A close relative of the prawn is the shrimp (*Cran'gon vulga'ris*), the tail of which is very much sought as food. This species is very widely distributed, for it lives in shallow water on both the Atlantic and Pacific coasts of North America, and the same species occurs in Europe.

Crabs. The species represented in Fig. 87 (*Pagu'rus pollica'ris*) is called the hermit crab, probably because it lives in a "house" by itself. The house consists of the shell of a dead snail, which may have been washed to the beach, or may have rested on the bottom of the bay. The hermit crab in its early life is pelagic, but at a certain stage of its development it sinks to the bottom, finds a snail shell, and backs into it; from that time on, the general shape of the body and the special modification of certain organs are determined by the form of the snail shell. The abdomen is soft, and all the abdominal appendages except the terminal ones are misshapen and useless. The terminal appendages extend laterally like flanges, and prevent the body from being drawn forcibly from the snail shell by an enemy.

The chelipeds are abnormally developed and, besides being of use in capturing prey, serve the important function of closing the aperture of the shell in times of danger.

Hermit crabs live in great abundance along gravelly beaches, where they are useful scavengers of dead animals in the water. In spite of the heavy houses which they carry, they move about with surprising facility. As suggested by one observer, they are wary, cunning, belligerent, and

FIG. 87. Blue crab and hermit crab. ($\times \frac{1}{4}$)

cowardly, making great pretense of fighting, but on the first show of force by an opponent withdrawing into their shells.

A small, shore species more frequently seen never becomes as large as *Pagurus pollicaris,* which is a deep-water species. All the species, however, when the individuals are young, choose small shells; as they grow older and larger after each molt, the unused space in the shell becomes less and less. Naturalists have observed the action of hermit crabs that have become too large for the shell. The animal searches about for a suitable larger shell, and when it finds one withdraws its body from the old shell and extends it into the new.

The spider crab (*Libin'ia emargina'ta*, frontispiece) stalks slowly over the sea bottom in shallow and deep water where rocks and fixed plants and animals abound. It can neither run nor swim, an inference which might be drawn from the slender, stilt-like appearance of its legs. Having no means of aggressive defense, it relies almost wholly on the fact that its color is very much like its surroundings. The cephalothorax is covered with coarse, hair-like, flexible spines, and the general color is dull gray. Frequently we find on the back small seaweeds, hydroids (p. 271), sea anemones (p. 275), and even rock barnacles (p. 166), growing as they would on rock. This protective resemblance appears to be very successful from the point of view of the spider crab, for it is in some regions more abundant than any other kind of crab. In some parts of Long Island Sound the spider crabs are so numerous that they get into the lobster pots set by fishermen and crowd them so that no inducement remains for the lobsters to enter, much to the disgust of the fishermen. Along the Atlantic coast this species grows to have chelipeds which extend over one foot from tip to tip. The giant Japanese spider crab has chelipeds which extend over fifteen feet from tip to tip, and has a body correspondingly large.

The edible crab, more frequently called by naturalists the blue crab (*Callinec'tes sap'idus*, Fig. 87), is characterized by having sharp lateral spines of large size, and by the last pair of thoracic appendages being flattened and adapted to swimming. The chelipeds are strong and fitted for cutting; the succeeding three pairs of appendages have no nippers, but come to a point.

As is well known, the blue crab is caught in large numbers along the Atlantic and Gulf coasts for the markets in the cities. The industry is of considerable value commercially, and for that reason very general attention has been

given to the distribution and habits of this crab. It is caught most easily soon after the molting, which takes place in early summer, and is then called a soft-shell crab; at this time also the species is considered most valuable as food.

The blue crab is not confined to the salt water, for it is found frequently in rivers some distance from bays. Wherever they are, they devour much of the organic waste that flows down to the sea. They are therefore important as scavengers.

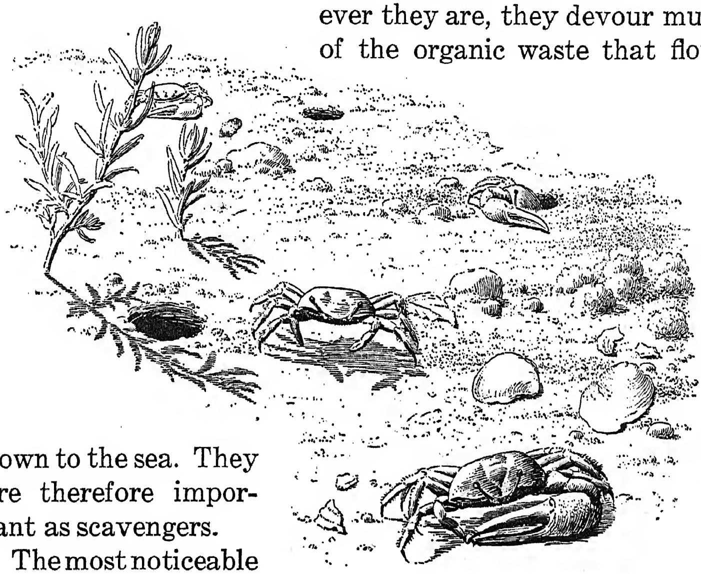


FIG. 88. Fiddler crabs. (Slightly reduced)

The most noticeable thing in the structure of the fiddler crab (*U'ca pugila'tor*, Fig. 88) is the presence in the males of a large cheliped. Sometimes it is the right one that is larger, and sometimes the left one; the females have their chelipeds small and of equal size. The name "fiddler" is supposed to have been derived from the fancied resemblance of the large cheliped to a fiddle, and of the small one to a bow.

The Sow Bug. The sow bug, and a related species called the pill bug because of its habit of rolling up into a ball, are found under stones, boards, logs, and in other dark, moist

places. The flattened condition of the body reminds one of the cockroach, which shows the same adjustment of the form of the body to the necessities of life. The species represented (Fig. 89) belongs to the genus *Onis'cus.*

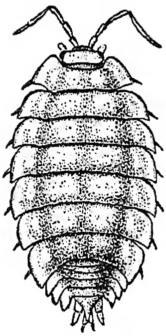


FIG. 89. Sowbug. (×3)

The body has twenty somites, as have the crayfish and all the forms described so far in this chapter. A pair of short, jointed antennæ and a pair of compound eyes without stalks, that is, *sessile* eyes (Lat. *sedere,* "sit"), are the most noticeable organs of the head. They have a second pair of antennæ, which are rudimentary. The mouth parts are small and adapted to feeding on plant food. The breathing organs are gills, protected by flat, plate-like structures on the under surface of the abdomen. The female bears a brood pouch on the under surface of the body, in which the eggs are carried and the young develop.

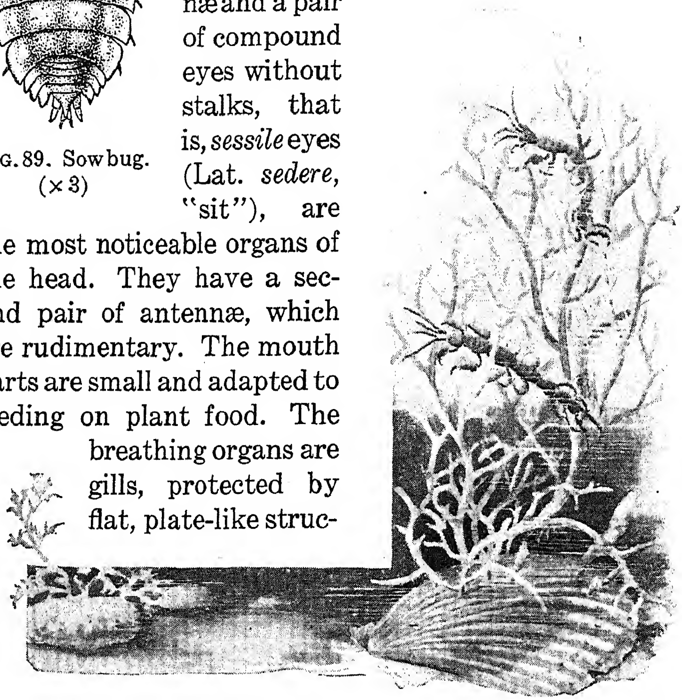


FIG. 90. *Caprella.* (× 2)

Caprella. Probably one of the strangest-looking free forms to be found in the sea is the little, brown *Caprel'la geomet'rica* (Fig. 90). It lives among seaweeds, on which it can be discerned with difficulty.

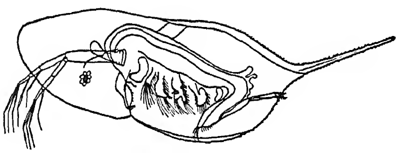


FIG. 91. *Daphnia*, a water flea. (Much enlarged)
After Forbes

Water Fleas. Water fleas (*Daph'nia*) have the body inclosed in a shell (Fig. 91). The feathery antennæ are used for swimming. The many different species of water fleas are among the most abundant animals in lakes and rivers. Many kinds of fishes feed upon these minute crustaceans. The eggs and young are carried inside the shell at the back of the body.

Cyclops. Any fresh-water pond will afford millions of specimens of the genus *Cy'clops* (Fig. 92), and the sea contains species of the same genus in such numbers that they with allied genera form a large part of the food of many fishes, and even some species of whales find in them an abundant food supply. Their powers of reproduction are so enormous that it has been estimated that the descendants of one Cyclops may number, in one year, 4,500,000,000 individuals. Though microscopic in detailed structure, on close observation it is easy to see them darting spasmodically through the water in aquariums. A single compound eye in the middle of the head gives them their name, in reference to the race of mythical giants of Sicily. Two pairs of antennæ, used in locomotion, extend from the front of the head. The legs are

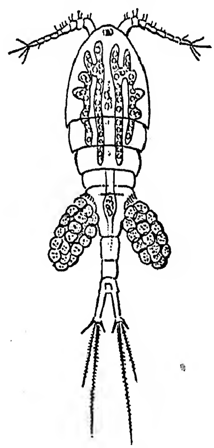


FIG. 92. *Cyclops*. (Much enlarged)
After Claus

two-branched appendages, also used in swimming. One pair of antennæ and the legs are not shown in the figure. Two long appendages extend from the end of the abdomen. The body consists of fifteen somites, five in each of the three regions, head, thorax, and abdomen. The female, in the summer season, carries about with her two large brood sacs of eggs, which extend diagonally out behind.

Parasitic Crustacea. A large number of different forms resembling *Cyclops* in many respects have adopted a parasitic life. They occur on various hosts, but the greater number of them are found on fishes. They live on every part of the body. Some live in the alimentary canal, or in the gill region, feeding only on the food of the host; some temporarily seek their host for the body fluids, while others are permanent parasites external or internal. In general these forms are spoken of as "fish lice." To the extent that they are dependent on a host, the normal, external structure tends to be modified out of all resemblance to the type represented by *Cyclops*. The somites lose their distinctness, and the form of the body is altered by protuberances of various kinds. The mouth parts become adapted as holding and sucking organs. As the external organs degenerate, the tendency of certain internal organs is also to become rudimentary. Some of these parasitic organisms are so degenerate in form and structure that they have lost all appearance of being animals at all. In many cases it is the female only which is parasitic, the males leading a free life and showing the normal structure of their race.

Barnacles. Despite the great apparent difference between the fixed, shell-bearing barnacles and the free-swimming crabs and other forms discussed in this chapter, naturalists have shown that they are in reality closely allied both in development and in structure. In some places barnacles literally incrust the coast-rock between tide lines with hard,

sharp-edged shells, composed of carbonate of lime. One species lives on the backs of whales. The shell is usually a little over a centimeter high, and narrower at the top than at the base. Related species grow to be at least four centimeters high. At the top of the rock barnacle are two hard, movable valves, meeting in a median line, which, on opening, expose long, feather-like processes. These feathery processes are the feet. The animal lies on its dorsal surface within a several-valved shell, and by rapid movement of the feet creates currents of water which bring to the mouth microscopic animals and plants as food. When the feet are not scooping in food the valves are closed, forming a most effective armor for the parts beneath.

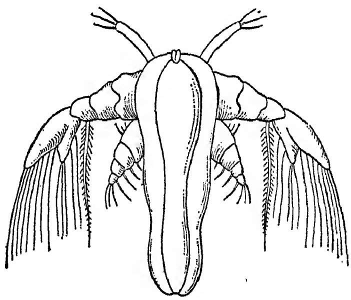


FIG. 93. Nauplius stage of *Artemia*. (Much enlarged)
After Joly

Though the barnacle in its adult condition, as just described, has nothing to fear, in early life it swims free at the surface of the water in the midst of millions of the young of crabs and other animals. There it is subject to the attacks of animals which might devour it, and many young barnacles are undoubtedly destroyed. At this time it would not be recognized as a barnacle by those who have seen only the adult form. It has an unsegmented body, a long upper lip, single median eye, as in *Cyclops*, and three pairs of jointed legs. This larval form is called a *nauplius* and resembles Fig. 93. The barnacle nauplius stage undergoes further complicated changes before it attaches itself by the head to some solid object, as a rock, pile, or ship bottom, when the swimming appendages are absorbed and the shell and feathery foot processes are developed.

Trilobites. Some of the most abundant of the forms in the earlier periods of life on the earth were the *tri′lobites* (*Pha′cops cauda′tus,* Fig. 94), which are an extinct type of the Crustacea. They are named trilobite from the apparent division of the body longitudinally into three parts. The length of the body varied from a fraction of one inch to two feet. They are thought to have lived in shallow water along shores, and through a long period of the earth's history must have been a most characteristic feature of the fauna of the world. Of the many species of trilobites not one remains living at the present day.

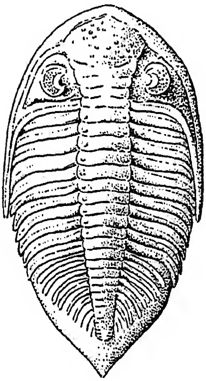


FIG. 94. Trilobite

Taken from a report of the Geological Survey, United Kingdom

Definition of Crustacea (Lat. *crusta,* "shell"). The crayfish and the species mentioned thus far in this chapter belong to the class Crusta′cea. They are constructed on the plan of a series of body divisions (somites) seldom exceeding twenty in number. The somites are usually bilaterally symmetrical (uniform in structure on either side the median line). Typically each somite has a pair of branched, jointed appendages. Two pairs of antennæ are present. The exoskeleton contains chitin and carbonate of lime. Crustacea are essentially aquatic in their habits and, with the exception of the lowest forms, breathe through gills. Nine tenths of the class are said to live in the ocean, some in fresh water, and relatively few species on land.

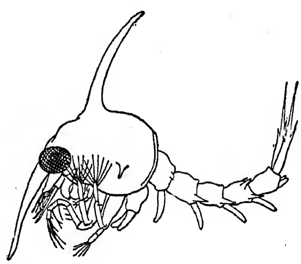


FIG. 95. Zoëa stage of crab. (Much enlarged)

After Emerton

As in the insects, the hard exoskeleton necessitates frequent molts to provide for growth, and also, as in that class, growth is sometimes accompanied by marked metamorphosis after hatching. Many of the Crustacea have direct development from a rather simple larval stage (Fig. 93). However, the lobsters (Fig. 86) and the crabs (Fig. 95) undergo a more complicated development, in which the individual passes through several different larval forms before reaching the adult condition. In the crayfish the development is similar to that of the lobster with the exception that the various larval stages are passed before the egg is hatched. Thus in the crayfish the young does not leave the egg until it has passed through these stages and closely resembles the adult.

Animals related to Crustacea and to Hexapoda

There are several groups of animals which in some respects resemble the crustaceans and the insects. But these differ so much from their nearest relatives in certain characteristics that they are now considered as belonging to several independent classes. A number of these forms are inconspicuous and have value for the advanced student only. The familiar forms commonly known as the centipeds and the millipeds are the only members of these groups that will be discussed here.

Centipeds. The common centiped (*Litho'bius*, Fig. 96), found under the bark of trees, is an elongate, flattened animal, with long antennæ, many somites, and a pair of legs on every somite. There is a poison gland in the base of the first pair of legs, which is used to kill earthworms and insects, upon which *Lithobius* feeds. The house centiped (*Scutig'era*) feeds largely on flies, cockroaches, and other insects.

Centipeds are widely distributed over the world. In the tropics they grow to be over thirty centimeters (one foot)

long. Some species are poisonous, even to man, and death has been known to result from their bite. They are active creatures and feed on living animals. The number of somites varies from about nine to over two hundred. A pair of legs is attached to each somite. The following lines were

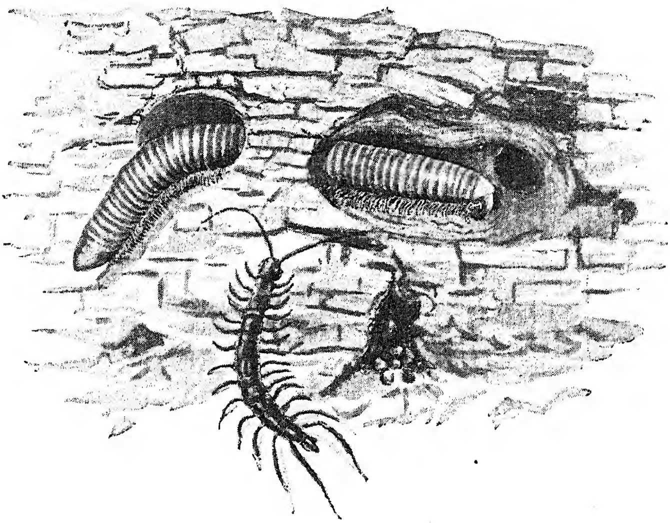


FIG. 96. Centiped (below) and milliped (above). (Reduced)

written by Sir E. Ray Lankester, of England, after an attempt to study the order in which the legs were moved:

A centipede was happy — quite
Until a toad in fun
Said, "Pray, which leg moves after which?"
This raised her doubts to such a pitch,
She lay exhausted in the ditch,
Not knowing how to run.

Millipeds. Other elongate forms called millipeds (*Spirob'olus*, Fig. 96) may be distinguished from the centipeds by the more cylindrical body. Millipeds also possess a greater

number of legs than centipeds, each somite, with the exception of several coming directly after the head, bearing two pairs of legs. They live in damp places and feed on living or decaying vegetable matter; they are entirely harmless. Many have the power of coiling themselves up when disturbed. The larvæ, when first hatched, have few somites, and but three pairs of legs.

Definition of Arthropoda. The animals described so far in this book belong to the phylum (see page 109) Arthrop′oda (Gr. *arthron*, "joint"; *pous* (*pod-*), "foot").

The body of an arthropod is made up of bilaterally symmetrical somites arranged in a linear series. There is always a head composed of from four to six fused or united somites. The somites of the remainder of the body are grouped into one region, the trunk (centipeds and millipeds); or into two regions, thorax and abdomen (Hexapoda, some Crustacea). The head is sometimes fused with the thorax, the abdomen being a distinct region (Arachnida, some Crustacea). Appendages, wherever present, are jointed. Except in the millipeds they occur as a single pair on each somite. The somites and appendages are covered with a chitinous exoskeleton; in some members of the phylum the exoskeleton is very hard and filled with carbonate of lime.

The digestive tract extends nearly straight through the body from the anterior end to the posterior end. The blood, which is usually colorless, is carried through the body in a partially complete system of vessels with a tubular, or heart-like, pumping organ in the dorsal region of the body cavity.

Respiration takes place through gills (Crustacea), lung-like sacs (Arachnida), or through an internal network of tubes (tracheæ) opening in two lateral series on the exterior of the body (centipeds, millipeds, insects, and some arachnids).

The nervous system generally consists of a "brain," dorsal to the gullet, two connectives passing one on either side of the gullet and uniting below to form a ganglion, from which a double nerve cord extends along the ventral body wall to the posterior end. Sense organs characteristic of the phylum are jointed antennæ, and simple and compound eyes.

From the foregoing statements we come to recognize a few features as distinctive for all arthropods. These distinguishing characteristics are a segmented body covered with a chitinous exoskeleton and with jointed appendages arranged in pairs.

CHAPTER XVII

HEREDITY AND EVOLUTION

A fire-mist and a planet,
A crystal and a cell,
A jelly-fish and a saurian,
And caves where the cave-men dwell,
Then, a sense of law and beauty,
And a face turned from the clod;
Some call it Evolution,
And others call it God.

CARRUTH

Although every species of animal tends to produce young resembling itself, no two individuals even of the same species are ever precisely alike. That the young of each species tend to resemble their parents, we say is due to *heredity*; that they never exactly resemble them, we say is due to *variation*.

Variations. As a rule, the differences between animals of the same species are slight. However, an occasional individual different from any of its kin in certain respects may make its appearance. This difference may be conspicuous, such as a change in color, or very inconspicuous and affecting only some small organ or structure of the body. The abrupt appearance of individuals showing differences from their relatives is spoken of as *mutation*, and the individual is called a *mutant* or a *sport*.

Artificial Selection. Animal breeders have known for a long time that many of the ordinary differences and the mutations which occur in their flocks and herds are passed from one generation to the next. In fact, they have used both these kinds of variations in producing more desirable

types of live stock. From each generation the stockman selects his best cattle or his best pigs as breeding stock. By best he means those which come the nearest to his idea of what a perfect animal should be. Thus if he is raising cattle chiefly for meat, he selects the largest animals. On the other hand, if he is interested in producing milk, he chooses those animals which yield the most or the best milk, with little regard for the size or form, which concerned the meat producer. His choice of breeding stock is called *artificial selection*. In this manner, beginning back before the dawn of history, man has gradually improved his domestic animals. In consciously selecting desirable traits for his breeding stock he has at the same time eliminated many undesirable characteristics from his flocks and herds, for desirable as well as undesirable traits are passed on from generation to generation by heredity.

New races and breeds of domestic animals (Fig. 97) differing in many respects from each other are being produced continuously. Some of these have existed for a long time, others have been produced within the past few years. A Percheron horse and a thoroughbred saddle horse are extremely different in appearance. But we know that man by his own choice has produced these and many other breeds of domestic animals by selecting from stocks that were originally alike. Most of the many breeds or races of domestic animals breed true. This means that two individuals of the same breed produce young like themselves except for that degree of ordinary variation which marks all individuals. Occasionally sports, or mutants, utterly different from their relatives in certain respects make their appearance in breeds of domestic animals. Some of these mutations are hereditary and are utilized to change the character of a breed. Hornlessness in cattle is a condition that has existed for a long time in some breeds, and in other breeds

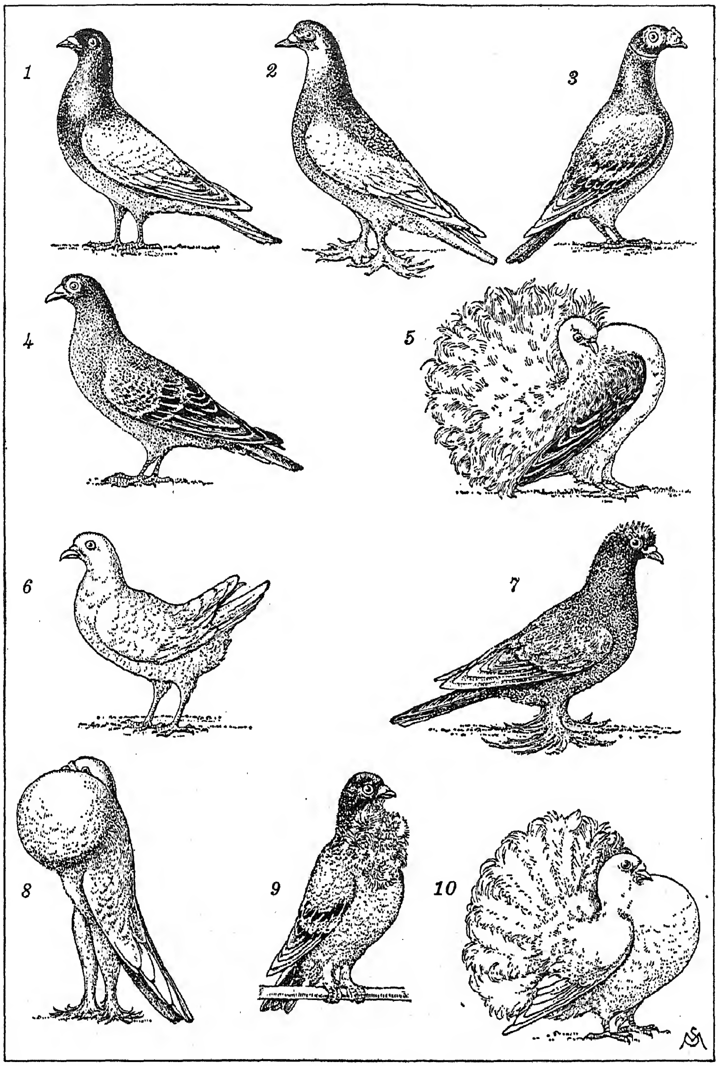


FIG. 97. A few of the many varieties of cultivated pigeons

These varieties, and others, have been developed from the same stock or ancestry. *1*, silver runt; *2*, muffed tumbler; *3*, dragoon; *4*, homer; *5*, saddle fantail; *6*, white maltese; *7*, English red trumpeter; *8*, white pouter; *9*, English owl; *10*, white fantail. (After Gruenberg)

mutants of the hornless condition have arisen from pure stock within recent times.

From the foregoing paragraphs we see that the inherent tendency to vary, whether slightly or conspicuously, has furnished the material with which man has worked to produce his various breeds of domestic animals. By selection man has obtained forms so widely different from each other that if they occurred in nature we should not hesitate to call them distinct species. Yet we know enough of their histories to know that one breed of horses or of cattle has been developed from another. This gives us the idea that animal forms are plastic and may change, producing new breeds or varieties. Heredity operates on those characters wherein the individual differs from others of its kind just as well as on those characters which are borne by all members of the race or breed. By the method of artificial selection man makes the two contrasting forces of heredity and variation work together to produce new races of animals.

Mendel's Law of Heredity. Man has long sought for a means of explaining how heredity operates. Since the opening of the twentieth century much progress has been made toward an understanding of laws, or principles, governing heredity. Studies have been made on many different kinds of animals representing most of the important groups of the animal kingdom. Out of these experiments there have come definite laws, by means of which it is possible to predict with reasonable certainty what kind of offspring will be produced by two individuals. Although many other laws and principles are involved in the study of heredity, the real explanations started with the work of Gregor Mendel. He was an Austrian monk who experimented with garden peas, and in 1865 he communicated his discoveries to the Society of Naturalists at Brunn. These have since been described as "the greatest discovery in biology since Dar-

win." Mendel's work received little attention at first, but a full generation later a Dutch scientist, de Vries, rediscovered the work of Mendel. In 1900 Mendel's work became generally known to the scientific world. Since that date the study of heredity has been the most actively pursued of all the branches of biology. There have been an extremely great number of studies in which it has been shown that heredity of given characters follows the principles laid down by Mendel. In studying the operation of heredity it has been discovered that some of the conditions which we ordinarily think of as simple are really due to several different causes. This has led to the use of the term *unit character* to distinguish those traits or characters which pass as indivisible units from one generation to its offspring.

According to Mendel's principles, when mating occurs between two animals of the same species (Fig. 98) differing in but one of the many unit characters, the offspring will often show not a condition intermediate between the two parents but the character which appeared in only one of the parents. Thus the offspring of one white and one black guinea pig will be not gray but black, in color agreeing with one of the parents, not intermediate between them. A character from one parent which impresses itself in the offspring to the exclusion of the contrasting character from the other parent is said to be *dominant*. In contrast, the character which is not seen in the offspring of the first generation (or F_1) is said to be *recessive*. If experiments were not carried further than one generation it might seem that the recessive character is entirely lost. But when the experiment is carried further, new facts are brought out. When the black guinea pigs, whose parents were one black and the other white, reach maturity and are bred together their offspring will be some of them black and some of them white. The proportions of the black and the white individuals in this second gen-

eration follow definite laws. Of course, in a single litter the numbers may be different, but if large numbers of individuals are considered the second generation of young (called F_2 for convenience) from the black and white grandparents will be in the ratio of three blacks to one white. If white individuals of this second generation are bred together they produce nothing but white young even though the grandparents were coal black. If the black guinea pigs of the second, or F_2, generation are bred together we find that though they all look the same there are two different kinds

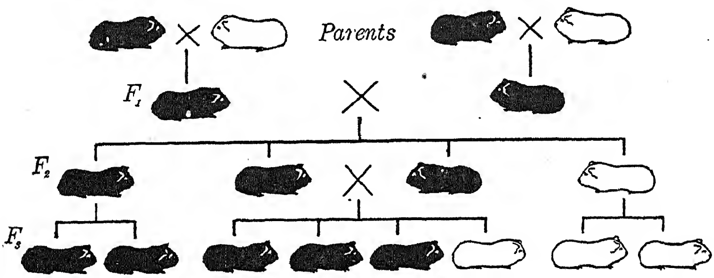


FIG. 98. A diagram showing how hair color is inherited in guinea pigs

of the black individuals. One out of three of the black animals of the F_2 generation can produce nothing but black offspring, and two thirds of the black individuals of the F_2 generation, when bred together, may produce either white or black young. Those individuals of the F_2 generation which are capable of passing only their own color to their offspring are said to be *homozygous*. In contrast, those which may have offspring either like themselves or showing the recessive character are called *heterozygous*.

Since each individual has its origin as a pair of germ cells which unite to form a fertilized egg, we must go back to the germ cells to seek an explanation of how heredity operates. It is very generally agreed that the chromatin within the nuclei of the germ cells is the material concerned in matters

of heredity. This chromatin does not contain black hair or anything resembling the other characters which it passes on from parent to child. It is simply material which causes development to go in a certain manner. The chromatin is said to be a determiner of characters though in itself it does not possess the characters.

It will be recalled that when cells divide by mitosis, the chromatin becomes arranged in minute bodies called chromosomes (Figs. 71, 72). The ability to determine a great number of hereditary characters must be present in each chromosome. For instance, in the fruit fly (*Drosoph'ila*) more than four hundred different hereditary characters have been studied. Yet this fly has but four chromosomes in each germ cell. This gives some idea of how very numerous and how extremely small each mass of chromatin for determining a single character must be. The name *gene* is applied to that particle of chromatin which determines a single hereditary characteristic. No one has ever seen a gene. From the way chromosomes behave in heredity, it is necessary to assume that these minute units exist in the chromosomes, though they are probably so small that even the best microscopes could not reveal them in the chromosomes.

In the ordinary cells of the body (except the germ cells) the chromosomes are recognizable as two sets. This may be understood if we remember that each cell of the body is formed by mitosis of the fertilized egg. Therefore each cell has the same number of chromosomes as were present in the fertilized egg. Two sets of chromosomes were united to form the fertilized egg. One of these was present in the egg before fertilization and the other was contributed by the sperm cell when it joined with the egg at fertilization. If both parents are alike with regard to a given character, both germ cells carry the same kind of a gene and the offspring will be homozygous. In the case of hair color mentioned above, if one

parent carries the gene for black and the other for white the offspring will be black because black is dominant, but the offspring will be a heterozygous black. This means that when the heterozygous individual comes to produce germ cells, half of them will contain the gene for black and the other half the gene for white.

In a human being there are many characters which are hereditary. Some of these are physical characters and are fairly easily recognized and studied. It seems probable that many other characters, such as mental traits, are likewise passed from generation to generation, but these are not so easily studied and measured. Brown eyes in man are dominant over blue eyes. Not every person who has brown eyes carries only the gene for brown, for many persons are of mixed inheritance or are heterozygous as to eye color.

When we consider the behavior of more than a single pair of characters, the problems of heredity become more complex. With the exception of a few instances each pair of characters acts absolutely independently of all other characters in heredity. In addition to the hair color of guinea pigs discussed above, the hair of these animals may be either short or long. Experiments show that short hair is dominant over long hair. Each of these two coat conditions occurs in both the black and the white individuals. If a black guinea pig with short hair is crossed with one having long, white hair, all the young will be black and all will have short hair, for both these traits are dominant. When members of this F_1 generation are bred together, four different kinds of individuals may be produced, two of which are entirely new combinations of the characters of the grandparents. The four different combinations are as follows: (1) animals with black, short hair like one grandparent; (2) animals with white, long hair like the other grandparent; (3) black animals with long hair; (4) white animals with short hair.

The last two types represent combinations of characters which did not exist in either the parents or the grandparents and which are different from conditions in any of their ancestors. In the offspring two characters which were originally associated in the ancestors may become separated and act entirely independently of each other. In breeding together members of the F_1 generation there is just the same chance for black to become associated with long hair as for it to remain with its original associate, short.

Many new varieties of plants and animals have been produced by new recombinations of characters like the example just cited. It was chiefly by methods of this sort that Burbank produced his many varieties of fruits and vegetables.

In the foregoing pages we have seen how new combinations of characters are readily explainable on the basis of definite laws of heredity. Further, we have observed the readiness with which man at his own pleasure creates new types of plants and animals by selection and by crossing individuals showing either slight or pronounced desirable variations. The question now arises as to the relation which exists between the differences among animals produced under man's direction and observation and the differences among animals in nature.

Fossil Animals. Students of fossil life of past ages (paleontologists) tell us that there are but few species of animals living today which are the same as those existing in the distant past of the earth's history. The early layers of the crust of the earth contain no remains of what we today speak of as the higher animals, or vertebrates (fishes, reptiles, birds, and mammals). Furthermore, these various forms of vertebrates did not all appear at once. There was a time when fishes were the highest type of animal living on the earth. In later fossil deposits remains of amphibians,

reptiles, and birds are found, indicating that these forms came into existence later than the fishes. Finally, mammals, the highest creatures of the animal kingdom, made their appearance, as shown by the fact that their fossil remains are found in late deposits but not in early ones. It has been well stated that the history of life on the earth has been written in tablets of stone. These give us an accurate, though incomplete, record of the fact that through the ages life upon the earth has been incessantly changing. Species of one age are different from, yet show undeniable relationship to, those of the age before. Age upon age has witnessed a gradual increase in the complexity of the animal population. The oldest fossil rocks contain nothing but the simplest types of animals. The most recent contain all the highest in addition to the lower forms. At intervals between these extremes we can point with certainty to the age when each group of animals first made its appearance. Evidently throughout the past history of the earth some factors have been at work, causing one species, or group, to give rise to different forms. There has been progress in this procession from the simpler to the more complex types of body. This progress is what is ordinarily called evolution. Evolution is a principle that seems to operate throughout the entire universe. All that the idea of evolution necessarily means is this progressive change, the evidences of which are all about us. When we go beyond this observable fact of a changing universe into the question of what has brought about the changes, we have entered another field. All scientists at the present time agree that evolution is a fact. Few agree in their attempts to explain how evolution operates.

Natural Selection. Charles Darwin worked out a theory to explain how evolution operates. This theory has been so much discussed and criticized that the average person thinks that Darwin's theory of natural selection embodies

the entire idea of evolution. In fact, natural selection is but one of many theories by which evolution is explained.

In introducing the discussion of natural selection Darwin makes use of the principle of artificial selection among domesticated animals. According to Darwin, something similar to this artificial selection by man goes on in nature, producing the different species of animals as we know them today. Stated briefly, Darwin's theory of natural selection rests on a series of arguments as follows: (1) there is a tendency for each species of animal to produce more individuals than can survive, because of lack of food, shelter, or other natural limits to numbers (overpopulation); (2) this overproduction leads to a conflict or contest between all individuals of the same species (struggle for existence); (3) in this contest all individuals having a handicap, or weakness, of any sort would be at a disadvantage in the struggle and would be the first to be starved or killed (elimination of the unfit); (4) thus only the best individuals, those having some superior trait of cunning, speed, strength, or the like, would live (survival of the fittest). According to this argument only the superior individuals of each generation would live and have opportunity to produce young. The very same advantages which permitted the parents to triumph over their less well-fitted brothers would be passed on to the next generation by heredity. Thus new traits, no matter how small, if they gave the owner advantages over his neighbors, would become emphasized. According to this belief Nature in a metaphorical sense chooses those individuals best suited to improve the race in a manner highly comparable to the part played by man in selecting his breeding stock from among his flocks of domestic animals.

In order to understand the principle of natural selection we must consider for a moment the struggle for existence.

This term is used by Darwin in "a large and metaphorical sense, including dependence of one being on another, and including (which is more important) not only the life of the individual but also success in leaving progeny." The struggle results from the tendency of living things to increase more rapidly than the means of subsistence. Professor Jordan of Stanford University says:

> If the eggs of a common house fly should develop, and each of its progeny should find the food and temperature it needed, with no loss and no destruction, the people of a city in which this might happen could not get away soon enough to escape suffocation from a plague of flies.

Professor Thomson of Edinburgh, Scotland, gives this illustration:

> A female aphis, often producing one offspring per hour for days together, might in a season be the ancestor of a progeny of atomies which would weigh down five hundred millions of stout men.

A rapid increase would be noted on the part of any animal, were the various checks to its multiplication removed. The struggle for life goes on between different individuals of the same species, as in a swarm of grasshoppers; between individuals of different species, as grasshoppers and insect-eating birds; and between living organisms and the conditions of existence, such as temperature, winds, moisture, and food supply.

The caddis flies are, in their immature stage, aquatic larvæ which build protective cases composed of grains of sand, or bits of straw, or leaves (Fig. 99). These cases afford concealment and protection to the young. Applying the principle of natural selection here, we may say that those caddis flies which varied in the direction of protective cases have survived, and those which did not have been devoured or otherwise destroyed; hence a race of case-building cad-

dis flies is in existence today. Natural selection results in "the survival of the fittest" for the particular environment, and the principle is used to explain the degeneration due to parasitism, as well as the development of increased complexity in animal structure.

Zoologists of the generation following Darwin attempted to explain all evolution as the result of natural selection. With the discovery of instances where natural selection obviously could not explain the course of evolution many at once declared the whole idea of natural selection worthless. The more we learn of nature the more does it appear that the operations of the universe are in accord with general plans or laws. But there is neither necessity nor reason to

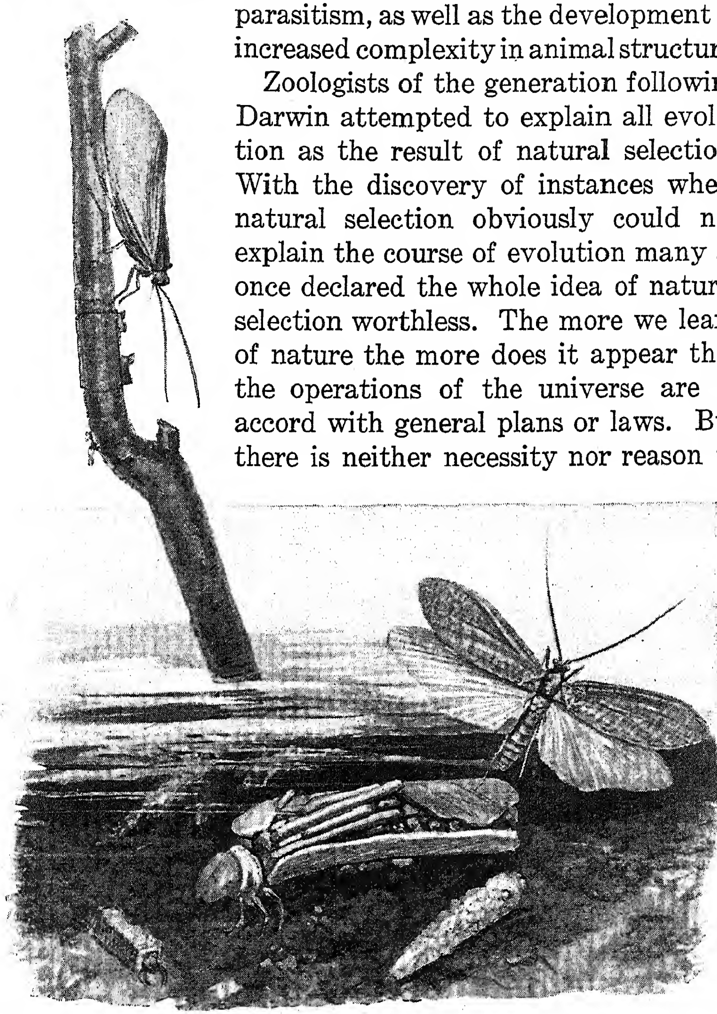


FIG. 99. Caddis flies. (Enlarged)

believe that but a single method produces a given result. It seems entirely probable that natural selection has played an important part in organic evolution. It is at the same time true that natural selection cannot explain all the changes that have taken place in the various types of animals.

Sexual Selection. The principle of sexual selection, also formulated by Darwin, is an extension of the principle of selection to account for the secondary sexual characters which exist in many animals. In most insects, where there is sexual dimorphism, the male, though usually smaller, is

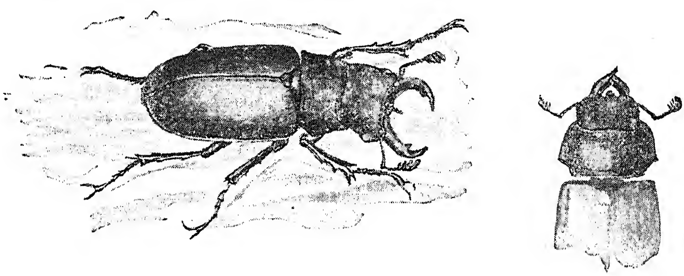


FIG. 100. Stag beetles (male left, female right). (Natural size)

more brightly colored; it is armed or ornamented with spines, which the female does not possess, or it has special sound-producing organs. In the common stag beetle (*Lu-ca'nus*, Fig. 100) the mandibles of the male are of larger size than those of the female. Among the birds, in those cases where the sexes are differently colored, the males are usually more brilliant; they often have spurs, wattles, crests, or plumes, while the females are without these structures, or have them in less degree. It is only the male birds, too, which possess the gift of song. Among the fur-bearers special characteristics, such as horns, antlers, and tusks, often occur. These various secondary sexual differences are ascribed by Darwin to sexual selection, which "depends, not on a struggle for existence in relation to other organic

beings or to external conditions, but on a struggle between the individuals of one sex, generally the males, for the possession of the other sex. The result is not death to the unsuccessful competitor, but few or no offspring. Sexual selection is, therefore, less rigorous than natural selection. Generally the most vigorous males, those which are best fitted for their place in nature, will leave most progeny. But in many cases victory depends not so much on general vigor as on having special weapons confined to the male sex. A hornless stag or spurless cock would have a poor chance of leaving numerous offspring." The greater brilliancy of many males is accounted for by ascribing it to the choice by the females, through countless generations, of the most brilliantly colored and attractive males. The song of male birds is accounted for in a similar manner.

The Inheritance of Acquired Characters. Though Darwin considered that species have arisen largely through the action of natural selection on favorable variations, he admitted also other factors in evolution on which some naturalists today lay great stress. It is a truism of our everyday life that the use of an organ sooner or later affects its structure. Thus the brawny arm of the blacksmith may be directly attributed to the kind of work he does. Among the insects we may instance the enlarged fore legs of the mole cricket and mantid, the enlarged hind legs of the grasshopper, and the absence of eyes in certain cave-inhabiting insects. With this principle are associated the names of Erasmus Darwin, grandfather of Charles Darwin, and the French naturalist Lamarck.

The chief difficulty in the application of the principle of the inheritance of acquired characters as a factor in evolution lies in the fact that we have little or no evidence that the characters acquired by use or disuse during the life of an individual are transmitted to its descendants. Many

unsuccessful experiments have been performed in the attempt to furnish this direct evidence.

The Mutation Theory. It will be remembered that Darwin laid stress upon indefinite, or fluctuating, variations as furnishing the material for selection. The mutation theory stands in sharp contrast with the selection theory in emphasizing the hereditary transmission of definite variations. With the mutation theory is associated the name of Hugo de Vries, a Dutch botanist of Amsterdam, Holland. He was led to express the principle from his studies of the variations in a species of evening primrose introduced from America and found growing in waste places near Amsterdam.

According to this principle new species have been produced by sudden and perfectly definite changes (mutations) in the organism, though it is not necessary to assume that these changes are always great. The theory makes no attempt to account for the presence of mutations, but when they occur it is a striking fact that the characters tend to be handed on to the descendants. Many of de Vries's conclusions regarding the mutations which he observed in primroses are today explained as due to impure stock giving rise to new combinations according to Mendel's principles. However, he formulated a principle which has become the basis of one of the most active fields in the investigation of heredity.

Experimental Study of Evolution. The study of heredity that is being carried on so actively in the research laboratories of all civilized countries is really the study of some aspects of evolution. New kinds of plants and of animals are being continually produced by artificial selection which essentially is very similar to the principle of natural selection expounded by Darwin. New mutations are being observed regularly in the laboratory experiments in genetics. It is becoming more and more obvious that Nature is not restricted to a single method of producing new forms of life.

CHAPTER XVIII

THE CLAM AND OTHER BIVALVES: ACEPHALA

And I then engaged myself, with the other merchants, in a pearl fishery in which I employed many divers on my own account.

SINDBAD THE SAILOR, in the Arabian Nights

THE LONG-NECK CLAM

Habitat and Distribution. The animal which is described first in this chapter is commonly known as the long-neck clam or the soft-shell clam. It is more accurately designated by its scientific name, *My'a arena'ria* (Fig. 101). As the specific name implies, the animal lives in the sand. It is found in great abundance along our Atlantic coast, even as far north as the Arctic regions.

External Structure. The *shell* of the clam has the same general use as the carapace of the crayfish. In both animals these hard, external parts protect the organs within from injury and also afford surface for the attachment of muscles. The clam's shell, however, is never molted. It grows continuously from the time it begins existence at the little rounded prominence called the *umbo* (pl., *umbones*), or beak (Fig. 101).

Anyone who examines a dry shell of this kind can tell which is the youngest portion of the shell. Probably he will observe at the same time the little spoon-shaped piece extending horizontally inward from one of the valves of the shell. This projection is always on the left valve. It meets a brown, rubber-like pad beneath the umbo of the right valve, and is joined with it. As long as the two valves hold together at this point, the pad, which is called the *hinge*

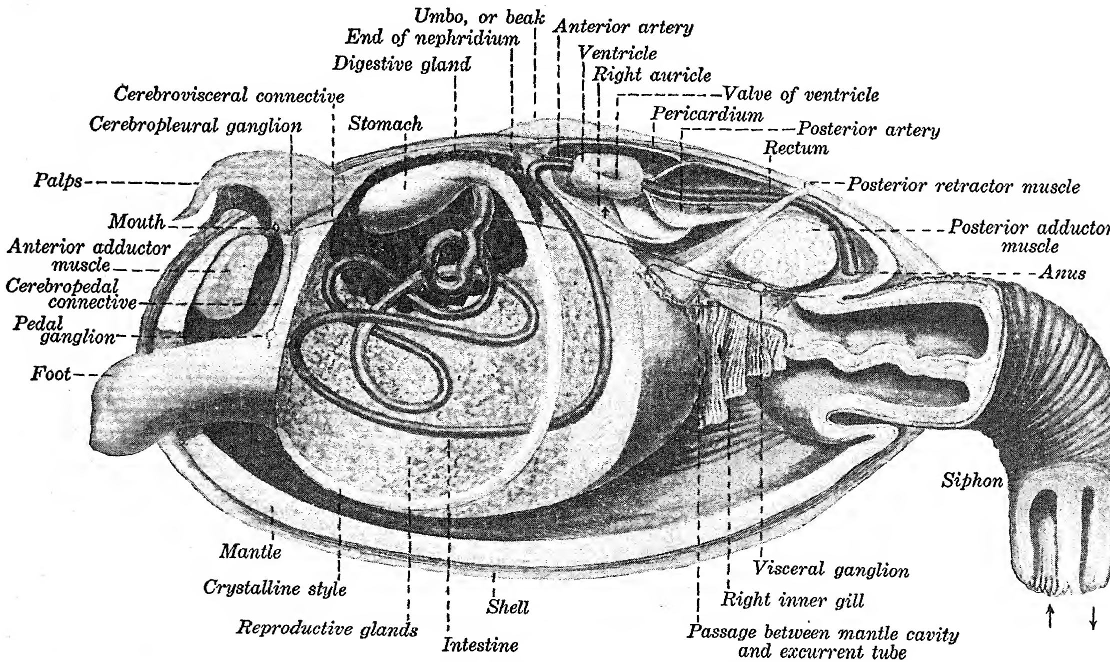


FIG. 101. Dissection of soft-shell clam. (Natural size)

ligament, has a tendency to separate the valves at an acute angle. In life two thick, short muscles extend across from valve to valve and resist the spreading action of the hinge ligament.

The Mantle and the Mantle Cavity. When the valves are shut they inclose a considerable space besides the body proper. Fig. 101 represents the most important organs as

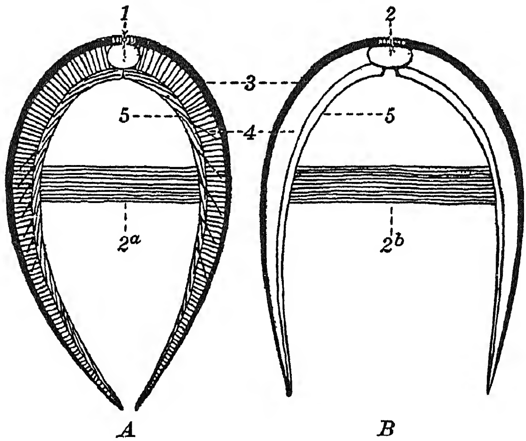


FIG. 102. Mechanism for opening and closing mussel shell

A, valves of mussel closed; *B*, valves of mussel open; *1*, *2*, hinge ligament; 2^a, adductor muscle contracted; 2^b, adductor muscle relaxed; *3*, outer layer of shell; *4*, middle layer of shell; *5*, inner (mother-of-pearl) layer [1]

they might lie in the hollow of the right valve. Fitting close to the inner surface of the valves is the *mantle* (Fig. 101). Except at the edge, where the *mantle folds* (halves) unite, the mantle is quite thin; its chief use is to secrete the calcareous substance of which the shell is composed. The shell is deposited in three layers (Fig. 102, *3*, *4*, *5*), — the outer layer called the *periostracum*, the middle layer called the *prismatic layer*, and the inner layer called the *nacreous* (or pearly) *layer*. After the shell is formed at the

[1] From Lang's *Lehrbuch*.

edge, the thin part of the mantle folds continues to deposit the nacreous layer, which is sometimes called mother-of-pearl.

The mantle folds inclose a *mantle cavity.* An opening at the anterior end of the mantle cavity allows the *foot* (Fig. 101), the single locomotor organ, to be extended to the outside. At the posterior end of the mantle cavity is situated the double-tubed *siphon* (Fig. 101). Only the lower tube of the siphon is connected directly with the mantle cavity. This siphon enables *Mya* to lie buried, anterior end down, in the mud and sand, still maintaining communication with the food-laden and air-laden water above. In large specimens of this clam the siphon is over twenty-five centimeters (ten inches) long.

The Digestive System. The ventral opening of the siphon (Fig. 101) is surrounded by many short tentacles which guard the passage. An ingoing current is created in the water by cilia on the gills. Ordinarily only microscopic food passes through this incurrent opening of the siphon. In the mantle cavity the particles of food are carried forward over the gills and along the mantle till they come within range of the waving *palps,* or mouth appendages.

The *mouth opening* is situated between the four palps, and is very small. It has no organs of any kind for seizing or chewing food; none are needed. The food once swallowed passes through the short *esophagus* to the *stomach.* Surrounding the stomach is the large, paired *digestive gland,* which secretes the digestive fluid. Situated in the end of the stomach, and in the anterior end of the intestine, we find, in *Mya arenaria,* and in many species related to it, an organ called the *crystalline style.* In *Mya* this structure is three or four inches long. It is soft and clear, like thick, colorless jelly, and lies in a long, thin-walled sac opening into the stomach. The style produces substances of use in the

processes of digestion and also aids in keeping the food well mixed in the stomach.

The *intestine* coils and twists in many planes from the posterior end of the stomach to the point where it penetrates the heart. The penetration of the heart by the intestine is of common occurrence in the class to which *Mya* belongs, but it occurs in no other class of animals. The part of the alimentary canal from the heart to the *anus* is called the *rectum.* The rectum is inclosed in a large, spindle-shaped organ of unassigned name and unknown function.

The Circulatory, Respiratory, and Excretory Systems. When the food is absorbed by the wall of the intestine it passes into small blood spaces filled with colorless blood. The blood with the contained food then passes into the open ends of small blood vessels. These blood vessels lead (in certain near relatives of *Mya* which have been studied more fully) to a large blood space below the *pericardium,* the sac which incloses the heart. From the blood space (not shown in the figure) blood passes by vessels to the *nephridia* (kidneys). The nephridia in *Mya arenaria* lie one on either side near the heart. The anterior end of the left nephridium is indicated in Fig. 101. The rest of the organ could not be shown in the drawing.

The nephridia are spongy, brownish organs of great complexity. Each nephridium of the clam opens at one end into the pericardium. The other end of each nephridium opens into the mantle cavity just posterior to the digestive gland.

The blood vessels in the nephridia divide into capillaries. The nitrogenous waste of the body (uric acid) passes into the nephridial tube and is carried out into the mantle cavity. The small blood vessels convey the partially purified blood into a vessel that runs along the line of attachment of the gills.

There are four of these *gills* and they hang like double curtains along the right and left sides of the body (Fig. 101). Oxygen, dissolved in the water, passes through the incurrent tube of the siphon into the mantle cavity and over the gills. The gills are thin and soft, and are thus adapted for the ready passage of oxygen to the blood vessels inside.

In the blood the oxygen combines with *hæmocyanin,* a substance analogous to *hæmoglobin* (see page 122). At the same time the waste carbon dioxide in the blood is given off to the water in the mantle cavity. The mantle folds, as well as the gills, take part in respiration. It is possible for them to do so because of their rich supply of blood vessels.

Returning from the gills and the mantle, the blood, freed of carbon dioxide, is carried to the *right* (Fig. 101) and *left auricles* of the heart. These thin-walled, sac-like reservoirs force the blood into the *ventricle* of the heart. The heart contracts and forces the blood both forward and backward through *arteries*. The anterior artery lies above the intestine, and the posterior artery lies below the rectum. Both arteries branch into smaller arteries in all parts of the body. The blood flows from the open ends of the smallest arteries into blood spaces, from which it is once more collected and carried to the purifying organs in the manner already described.

The Siphon. Besides the rows of cilia which carry food from the region of the incurrent tube to the mouth, there are rows of cilia on the body and along the mid-ventral line of the mantle, and it is known that these cilia wave toward the incurrent tube. Food that has been rejected, or waste that has accumulated, may be carried by the out-waving cilia to the base of the incurrent tube. By muscular contraction of the siphon at its base these substances may be expelled through the tube. The excurrent tube of the siphon, however, is the customary path of exit for substances

that are not used by the organism. All the undigested substances that pass through the intestine must leave the animal by the dorsal tube. In addition, it is likely that wastes from the nephridia, and from the gills and mantle, may pass from the mantle cavity through a slit-like opening (Fig. 101) at the base of the gills, and be carried out with the unused materials.

The Nervous System. In contrast with the nervous system of the arthropods with its long series of ganglia distributed through the length of the body, this system in the mollusks consists of but three pairs of large ganglia. Lying on the right and left sides of the esophagus, just posterior to the mouth, is a pair of *cerebropleural ganglia.* They are joined by a *cerebral commissure* running over the esophagus. As the name of the ganglia implies, there are two ganglia joined in each nerve mass. One pair controls the "head" region; the other pair controls the sides of the body close by. The cerebropleural ganglia are joined to the *pedal* (foot) *ganglion* by two *connectives,* one on either side. The pedal ganglion controls the movements of the foot. The *visceral ganglion* is joined to the cerebropleural ganglia by a pair of *cerebrovisceral connectives.* The visceral ganglion controls the organs in the posterior region of the body.

The Reproductive System. The pair of large gonads, which in male clams contain spermatozoa and in the females the eggs, lies in the midst of the coils of the intestine. Each gland has a short, slender tube, with an external opening (not shown) near the opening of the nephridium, just below the attachment of the gills.

Development. The very early history of the young *Mya arenaria* is incompletely known. We know, however, that after a short period of development and growth young long-neck clams swim about on the surface of the water. Soon after the appearance of their shell they sink to the bottom.

If they are fortunate enough to fall near the shore line, they anchor themselves to a seaweed, or to a pebble, by a tough, gelatinous thread (Fig. 103, *3*) which is secreted by a gland at the base of the foot (Fig. 103, *1*). This thread is called the *byssus*. In certain mussels found in the sea the byssus is a permanent and very complicated organ of the adult, but in *Mya arenaria* it disappears when the clam is about five millimeters (one fifth of an inch) long. At that time the animal burrows into the mud and sand, where it usually remains permanently.

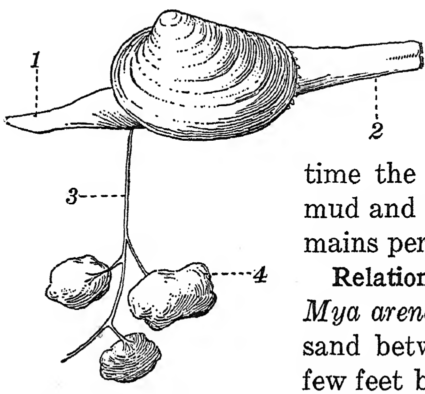


FIG. 103. Young long-neck clam

1, foot; *2*, siphon; *3*, byssus thread; *4*, pebbles. (After J. L. Kellogg)

Relation to Environment. The adult *Mya arenaria* lives in soft mud and sand between high-tide line and a few feet beyond low-tide line. The reason the clam lives in that situation is because food is most abundant there. Lying almost helpless in its mold of mud, the long-neck clam is rendered in a measure independent of conditions outside, as long as the currents of water carry the bountiful supplies of food over its burrow.

Although the clam is not so highly esteemed as an article of human food as its relative the oyster, it is nevertheless of great value.

THE AMERICAN OYSTER

Habitat and Distribution. The American oyster (*Os'trea virgin'ica*, Fig. 104) is found in shallow to deep water along the Atlantic coast from the Gulf of Mexico to Massachusetts Bay. As the artist has shown in the picture, the

animal lies attached to the bottom, frequently to another oyster shell. Although many oysters may live thus fastened to each other, there is no organic connection between them. They sometimes form clumps so large and heavy that the basal ones sink into the mud and die. The valves of the living ones extend outward at any angle. When oysters are not crowded in the "bed," the usual method of living is the one shown in the illustration. There the valves

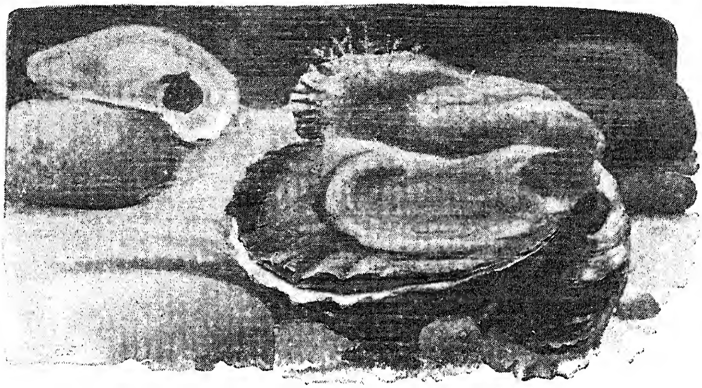


FIG. 104. Group of living oysters. (Reduced)

extend horizontally, and we can distinguish an upper and a lower valve. The lower valve is always much larger and deeper than the upper one. The lower one is the left valve.

Comparison with the Clam. The internal organs of *Ostrea virginica* and *Mya arenaria* are very much alike. The large, dark-brown digestive gland, the coiled intestine, the three-chambered heart, and the reproductive glands have a common plan in the two species. A noticeable difference is the entire absence of a foot in the oyster. Applying the principle of adaptation, we can readily explain the absence of that organ. There are two adductor muscles in the clam, in the oyster only one.

Development. In the months of May to September, in the latitude of Baltimore, the male and female oysters send out into the water their spermatozoa and their eggs. A female oyster may yield in one season at least sixteen million and probably as many as sixty million eggs. The number of male cells is great beyond all powers of expression. Of course we should expect that in spite of the countless spermatozoa, many eggs would never be fertilized at all, on account of their being carried away by unfavorable currents. Eggs that are not carried away fall to the bottom naturally. Those eggs which are fertilized swim to the surface as larvæ after a few hours' development. There surface fish may, as Professor William K. Brooks once suggested, "gulp down in a few seconds oysters equal in number to the population of Baltimore."

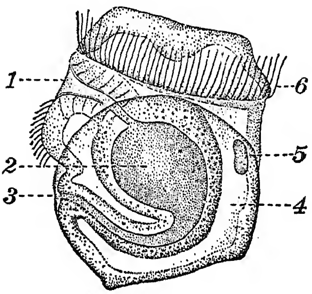


FIG. 105. Oyster larva. (Much enlarged)

1, mouth; *2*, stomach; *3*, anus; *4*, shell; *5*, adductor muscle; *6*, circle of cilia. (After Mœbius)

Within one to six days after fertilization the oyster "fry" (swimming larvæ, Fig. 105) sink to the bottom again and affix themselves to whatever solid object they happen to touch. At this time they are about three tenths of a millimeter (one eightieth of an inch) long. For a few weeks after beginning their stationary life they are liable to be crunched to death by voracious crabs, — among others, the blue crab (Fig. 87).

Economic Importance. The largest and most important "oyster farms" along our coast are in Chesapeake Bay. There and elsewhere the beds have been surveyed and leased under laws of the states. So vast is the oyster-fishing industry in this country that more than fourteen millions of dol-

lars are yielded annually by the oysters and their products. On the coasts of Holland, Belgium, and France far greater care is taken of their species (*Ostrea ed'ulis*) than we take of ours; but the natural conditions here are superior to the natural conditions there.

Oysters when subjected to sewage contamination may become carriers of typhoid fever. When grown and marketed under sanitary conditions they are not only harmless but a very wholesome food.

Relation to Environment. According to the pioneer investigations of Professor Brooks and others, oysters are to be found most abundantly in the quiet, semi-stagnant water of shallow inlets. Into such inlets slowly flowing creeks enter, giving to the water of the inlet a brackish quality. When food consisting of microscopic plants and animals is carried to the oyster by the natural currents in the water, it may enter at any point between the separate folds of the mantle. Cilia on the inner surface of the mantle folds, and on the four gills, sweep the minute organisms forward to the mouth, which lies near the hinge. The four palps aid in the process. In brackish water the most important food organism of the oyster multiplies in vast, invisible hordes. These organisms are plants called diatoms. Diatoms live in the soft mud at the bottom and are carried by the water currents within range of the cilia in the oyster's mantle folds.

In times of storm the home of the oysters' food may become a source of great danger to them. Once covered with mud or with shifting sand, the life of a bed of oysters is at an end. At the mouths of rapidly flowing rivers no oysters are to be found, chiefly because the silt (fine sediment) and the débris of decaying plants are unfavorable to the growth of the animal.

Aside from the physical agencies which are favorable or unfavorable to oysters, there are many animals which come

into definite and usually unfavorable relations to them. Only one of these animals, so far as known, is anything but harmful to the oyster. That one is a little crab, about thirteen millimeters (half an inch) wide, which spends its life in the mantle cavity of its messmate. The greatest enemy of the adult oyster is the starfish (Fig. 124). There are various boring snails, which make round holes through one of the valves with their rasping tongues and draw out what they need of the soft parts (compare Fig. 119). Another enemy is the boring sponge, which, as it grows, makes holes in the valves by a secretion which it produces. Like most other animals, the oyster has its parasites. With all these facts before us, the statement of Professor Moebius regarding the European oyster, that each oyster when born has $\frac{1}{1145000}$ of a chance to survive and reach adult age, seems well within reason.

The Scallop

Habitat and Distribution. Of all the shellfish that inhabit the shallow waters of the Atlantic coast of our country, none is more beautiful in color or in line than the common scallop, *Pec'ten irra'dians* (Fig. 106). Scallops are abundant among the eelgrass of shallow bays and inlets from the Gulf of Mexico to Massachusetts Bay. Above the latter region the waters are made colder by the arctic currents. *Pecten irradians* and many other species of sea animals do not live north of Cape Cod.

Relation to Environment. The very young scallop holds to some fixed object after the manner of a young soft-shell clam (Fig. 103). The adult scallop has no byssus, and only the rudiment of a foot. The scallop in the foreground of the picture is in what we might call the attitude of rest. It has released its single adductor muscle, which, we may say in passing, is the only part of the animal sold for food.

In the act of swimming the valves open and close quickly, by the alternate action of the hinge ligament and the large adductor muscle. On closing, the valves catch a quantity of water between the mantle folds. The water escapes under pressure from within, through a round opening at either end of the straight flange of the hinge. The resulting action of these jets of water backward, against the body of water outside, is to force the larger and broader end of the animal forward. When the scallop ceases swimming, it immediately falls to the bottom.

Shipworms. The shipworms are marine bivalve mollusks that have taken to burrowing in wood. The shell covers but part of the long, wormlike body. Piles and wharves and other wooden structures on the water fronts become honeycombed and are completely undermined by the burrows of these animals. They cause great damage in many regions along the coast.

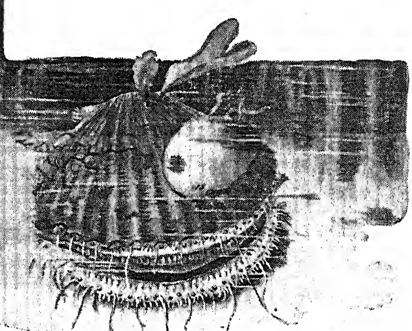



FIG. 106. Group of living scallops. ($\times \frac{1}{2}$)

The Fresh-Water Mussel

Habitat and Distribution. In fresh waters generally, wherever sufficient carbonate of lime is carried in solution, one may find mussels living nearly covered in sand and mud. The species represented in Fig. 107, *Ellip'tio complana'tus*, is distributed in the rivers and brooks of the Atlantic states.

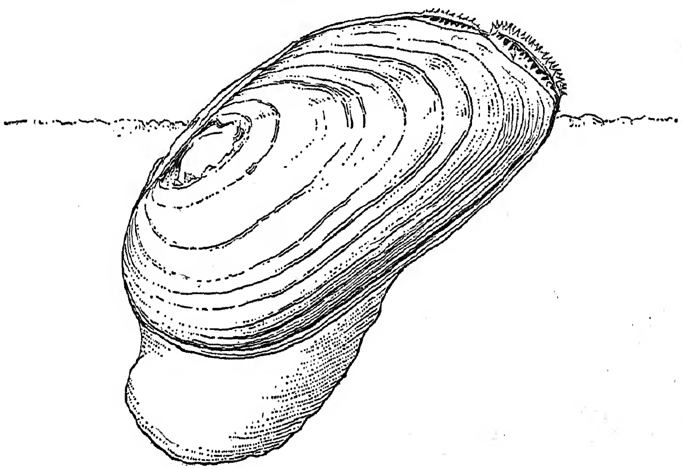


Fig. 107. Living fresh-water mussel. (× ½)

Comparison with Other Forms. The valves of the mussel are equal, like those of the clam and the scallop. The valves of the fresh-water species are held together by a hinge ligament, aided by two pearl-covered ridges running parallel and fitting into grooves. The mantle folds are not united as they are in the clam. The siphons are here merely openings between the two mantle lobes, not a protruding tube as in the clam. At two adjoining places in the posterior region the rim of the mantle folds is fringed with short tentacles. Dorsal and ventral openings, or siphons, are formed by the meeting of opposite edges at the places where the

tentacles occur. Water, bearing food and oxygen, is carried in by the ventral siphon, and undigested substances are carried out by the dorsal siphon.

The foot of the mussel is large and muscular. It enables the animal to plow its way through mud or even through heavy gravel. The gills and the palps are practically identical in structure in the mussel, the clam, the oyster, and the scallop. With the exceptions just mentioned, the organs have the same general plan of structure in the four animals named, and the description given for the clam applies to the three other forms. There are two adductor muscles in the mussel. The sexes are usually separate.

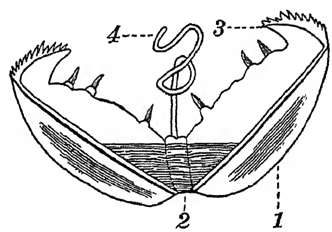


FIG. 108. Larva of mussel. (Much enlarged)

1, shell; *2*, adductor muscle; *3*, larval hook; *4*, larval thread. (After Balfour)

Development. All fresh-water mussels, except the small fingernail shells, carry their young in their gills. When fully formed, the larvæ escape from the brood pouch of the female mussel. Fish "nosing" along the river bed touch the young mussel, which at that stage is called the *glochidium* (Fig. 108). The shells of the glochidium clamp together and become attached to the gills or fins of the fish. Some species live only on gills and others on fins. For each species of mussel the larvæ will become attached to only certain kinds of fishes. After attachment the tissues of the fish grow around the glochidium, entirely surrounding it. For several weeks the glochidium is transported on the fish. During this time it may be carried into another river, even by way of the sea. When the period of development within the cyst on the fish is completed, the cyst, or covering, breaks away. This liberates the young mussel, which now ceases to be a parasite and begins an independent life. If

this happens in a favorable place, it burrows into the mud and begins the life of its adult kin.

Economic Importance. The distribution of fresh-water mussels has become a matter of considerable economic importance, especially in the states of Iowa and Illinois. Many factories have been established for the purpose of

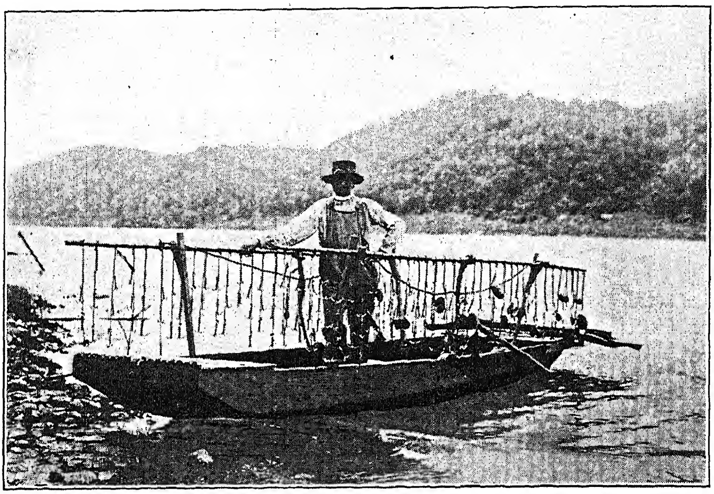


Fig. 109. Mussel fisherman with boat equipped for capturing fresh-water mussels

Photograph by F. M. Woodworth, courtesy of F. C. Baker

making pearl buttons from the valves. According to the annual report of the United States Bureau of Fisheries, approximately twenty-six thousand tons of mussel shells with a value of over one million dollars were taken (Fig. 109) by fishermen in 1922. These shells furnished material for over eight million dollars' worth of manufactured products, such as buttons and pearl novelties.

So many mussels have been taken from the streams (Fig. 109) in many regions that they have become practi-

cally exterminated. The United States Bureau of Fisheries has studied the problems of mussel propagation very carefully. In many of the streams commercial catching of mussels is prohibited in the hope of natural restoration. Fishing crews carry on rescue work to save fishes stranded in backwater ponds and bayous after high water. Before the rescued fishes are returned to the streams they are placed in tanks containing liberal quantities of glochidia. By this means each fish may carry several hundred young mussels back into the streams.

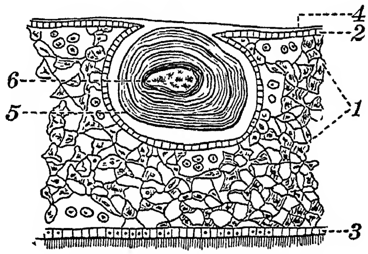


FIG. 110. Section of mantle fold of mussel showing how a pearl is formed

1, cells of mantle; *2*, external epithelium of mantle; *3*, internal (ciliated) epithelium; *4*, position of shell; *5*, pearl; *6*, remains of parasite. (After Jameson)

Pearls. True pearls of fine quality have been found in many species of mussels in all parts of the Mississippi Valley. In nature, pearls are formed around some irritating object. Parasitic worms and eggs of some of the small mites infecting the mussels are the most frequent bodies around which pearls are formed (Fig. 110). In reality, pearls are tombs incasing the bodies of intruders. Even sand grains at times become the nucleus around which certain kinds of pearls are formed.

Japanese scientists recently discovered methods of producing "culture" pearls by inserting objects inside the mantle. When perfect spheres cut from shells are introduced into the mantle, the culture pearls are almost perfect.

Relation to Environment. There are more than five hundred varieties of fresh-water mussels in the United States. Of these, some live only in muddy streams, and others are limited to sandy or to rocky bottoms. In streams, shallow waters, where riffles are formed, harbor the greatest number

of both species and individuals. Though they move about, the majority of individuals spend most of their time with the posterior end bearing the siphon directed upstream. Thus the flow of water downstream brings a continuously fresh supply of food to the animal. Fishermen (Fig. 109) make use of this habit. They always drag their clam bars downstream, so that the hooks may catch into the open shells. Mussels cannot survive in water that is polluted with sewage.

Definition of Acephala. The four animals described in this chapter are representatives of a class called Aceph′ala. Acephala means "without a head." They are called bivalves because the shell is in two pieces. Acephala are usually bilaterally symmetrical animals with an external skeleton composed of two nearly equal valves. They have no internal skeleton. The body is without a head and is not divided into somites. There are no jointed appendages. The mantle folds surround the body proper and secrete the shell substance. Locomotion is most frequently accomplished by a single muscular organ, the hatchet-shaped foot. The valves are held together by a hinge ligament, aided sometimes by ridge-like processes fitting into grooves. The valves are closed by one, or two, adductor muscles.

Four palps surround the mouth and carry the food inward. The esophagus is short. The stomach receives the secretion from a pair of digestive glands. The intestine coils several times and ends posteriorly. The circulatory system is nearly complete. There are two auricles and one ventricle in the heart. The pairs of glands of the reproductive system in male and female individuals seem to differ only in microscopic structure. In some species the sexes are separate. In others the individuals are hermaphroditic; that is, the male and female sexual glands are present in the same animal.

CHAPTER XIX

ALLIES OF THE ACEPHALA: MOLLUSCA

The frugal snail, with forecast of repose,
Carries his house with him where'er he goes.

CHARLES LAMB

The Pond Snail. Any one of several genera and species of snails that live in fresh water might be given the name "pond snail" with equal accuracy. The one represented in Fig. 111 (*Phy'sa*) is quite common not only in ponds but in rivers as well.

Externally the most noticeable feature of the pond snail is its thin, spiral shell. This structure is made of the same material as the shell of bivalves. A large portion of the animal's body fills the "mouth" of the shell and extends spirally toward the top. Between the shell and the body wall lies the mantle, which throughout life continues the growth of the shell in the characteristic spiral direction.

When the snail is disturbed it draws the entire body into the shell; but when it is feeding, as shown in the picture, one can see the long, muscular foot, broad in front and pointed behind. The anterior region of the body is the head, more or less sharply marked off from what lies behind. The mouth opens beneath an extensile upper lip. In the mouth is a short, muscular tongue, on which grows a long but minute ribbon of rasp-like teeth. The pond snail uses this rasping tongue to tear into bits the soft plant tissues on which it feeds. A most interesting experience is to watch a pond snail as it crawls slowly up the side of an aquarium, feeding on the microscopic plants as it goes. At

FIG. 111. Group of living pond snails. (Natural size)

such times one can see the mouth open and the tongue sweep back and forth, with tiny, rhythmic movements.

The two tentacles are organs of touch. The eyes lie one in front of either tentacle at its base. On the right side, and partly beneath the edge of the shell, is an aperture which opens over a small hollow space in the body when the snail comes to the surface. This space is the so-called "lung" of the pond snail. The lung is adapted to using the oxygen of

the atmosphere. Anyone who owns an aquarium containing snails may observe them crawling up the side of the vessel on their way to the surface. When they arrive there they remain for some time, opening and closing the lung to admit the air. In aquariums which have a supply of water plants growing in them, the pond snail does not appear to go to the surface so often. It is well known that plants give off oxygen. Some of this oxygen held in the water may pass through the snail's skin, which is thin and soft. The waste carbon dioxide of the snail is discharged into the water.

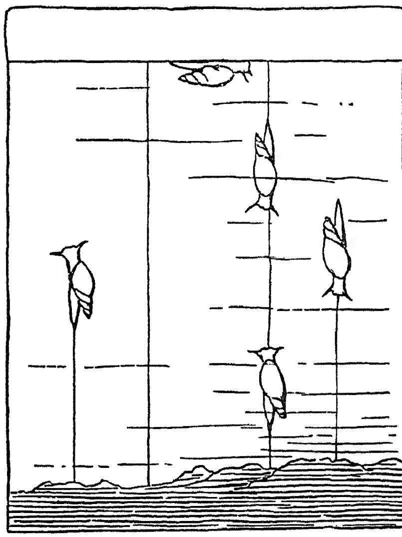


FIG. 112. Mucus threads of pond snail in water. (Reduced)
After Kew

It is not uncommon to see a pond snail crawling upside down at the surface of the water. The explanation of this curious phenomenon is the same as the explanation of how they can get along on any kind of a surface. Just below the mouth is the opening of a gland, which extends through the middle of the foot near the lower surface. If we look closely at the inverted snail, we can see the wall of this gland contracting with a wave-like movement in the act of sending the secreted mucus (slime) forward to be poured out at the opening. The mucus spreads out a short distance on the water, or blade of a water plant, or submerged object, and forms a bed over which the animal moves.

When the foot is extended in locomotion, the pond snail weighs less than an equal volume of water. If the animal releases its hold on an object at the bottom, it floats to the surface quickly. Conversely, if the animal releases its hold on the surface of the water, it draws the entire body into the shell and quickly falls to the bottom. In the second instance the weight of the snail's body is greater than the weight of an equal volume of water.

FIG. 113. Living land snail. (Slightly reduced)

We find vertical threads of mucus in snail aquaria and in ponds (Fig. 112). A snail on leaving the bottom may pour out mucus from its foot-gland in the usual way. The mucus fastened at the bottom will be paid out in the form of a thread as the animal floats slowly upward, held back by this thread. When the snail gets to the surface the thread is moored there in a patch of mucus. Each thread thus formed becomes a permanent pathway, tending to increase in thickness and in strength as the snail makes use of it.

In the spring and summer months the pond snail lays eggs even in captivity. The gonad is hermaphroditic, hence every individual is likely to deposit eggs. The eggs may be found on the branches of water plants, or even on the perpendicular sides of a glass aquarium, imbedded in an elliptical, clear, gelatinous mass from two millimeters to six millimeters long. In each mass from five or six to twenty-five eggs may be distinguished.

The Land Snail. One of the commonest of the land snails in America is the one shown in Fig. 113 (*Polygy'ra*). The many species of the genus *Polygyra* live in moist, protected places during the day and come out to feed at night. Frequently they leave their hiding-places in cloudy, damp, but not in rainy, weather.

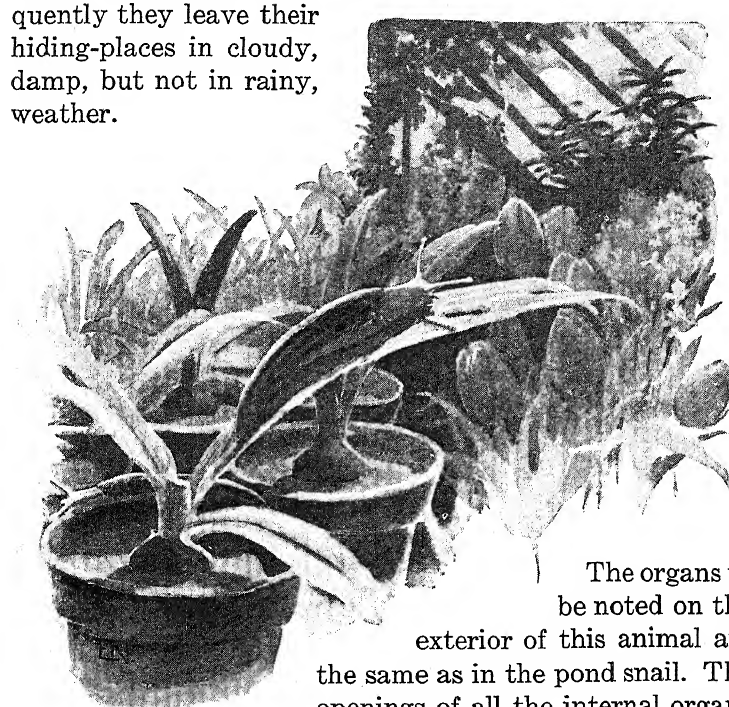


FIG. 114. Garden slug feeding at night. ($\times \frac{1}{2}$)

The organs to be noted on the exterior of this animal are the same as in the pond snail. The openings of all the internal organs occur in the same position in both animals. There are four tentacles in this land snail, — an upper, long pair bearing the eyes, and a lower, short pair, which are the organs of touch. The edge of the mantle is thickened to form a collar.

The Garden Slug. The particular species of garden slug of which the habits are suggested in Fig. 114, is *Li'max*

max'imus. It is a native of Europe, not of America, and since its introduction here has become a more unwelcome guest in greenhouses than any other species of slug or snail.

In brief terms we may describe a slug as a snail with a rudimentary shell. The elliptical plate of muscle on the dorsal surface of *Limax* is all that is left of the mantle. In the process of degeneration, which we may well suppose has occupied thousands of years, the mantle folded back over the shell as the latter decreased in size. If we examine the interior of the mantle, we find a thin, calcareous plate, which is the rudimentary shell.

The ravages of *Limax maximus* are not serious if the florist does not allow refuse to collect about his buildings. Many adopt the method of scattering ashes or cinders about the plants to be especially protected. A slug crawling into such an obstruction is stimulated by the dryness of the ashes, or the roughness of the cinders, to secrete mucus from the glands that occur in the skin. This mucus is like that which is secreted from its foot-gland while crawling. Owing to the unusual amount of mucus given off at such times, the animal dies from exhaustion, and from suffocation by the drying of its skin.

Garden slugs that live out of doors burrow into the ground and curl up when the coldest weather comes. Those in greenhouses remain active throughout the year.

Several other slugs, some of which are smaller and much more widely distributed than *Limax maximus*, occur under logs and damp leaves. At times these become numerous enough to do considerable damage in gardens.

The Oyster Drill. A few minutes' walk along almost any pebbly beach between Florida and the Gulf of St. Lawrence would afford a collector the opportunity of observing the subject of this description, the oyster drill (*Urosal'pinx cine'rea*, Fig. 119). In such a walk the artist discovered the

unfortunate periwinkle at the left of the picture, with the oyster drill of the foreground engaged in devouring the soft parts of its victim through the hole made in the thick shell. For the purposes of illustration the oyster drill was placed on another periwinkle in the same position it occupied on the first when discovered. In deep water the oyster drill devotes itself to the business which gave it the name it bears. There are several other species of snails, however, which have the same habit of boring through the oyster's valves and feeding on the soft parts.

The oyster drill, in common with all other species of snails that have their habitat on the seashore, possesses a very thick shell, adapted to the severe conditions of life there. The sand and pebbles are constantly shifting under the pressure of the waves, and only those snails that have thick shells can endure the conditions.

The Periwinkle. The periwinkle, a littoral (shore) species (*Littori'na litto'rea*, Fig. 119), is a native of Europe. Its presence here is accounted for by the supposition that specimens were accidentally thrown in with the gravel used for ballast on ocean-going vessels, and thrown out again when the vessel reached its port in America. The first specimens noticed in America by conchologists (students of shells) were reported at Halifax, Nova Scotia, in 1857. Since that time the periwinkle has been making its way down the coast. It may now be found in southern waters. The new home in America seems to be especially favorable for the periwinkle, for on the rocky coast of New England there are so many of them that on first impression there appears to be no other species. This snail depends on plant food altogether.

On account of its great abundance the periwinkle is much used as an article of human food in England and on the Continent. It is one of the many species of snails and slugs used as food, especially by the French people.

The Nudibranch. The strange-looking creature shown in Fig. 115, *Dendrono'tus arbores'cens*, is to be found on seaweeds and under submerged rocks along the north Atlantic coast.

Tree-like processes grow on the upper part of the body. These processes are to some extent used in respiration. Since they are thin, oxygen can pass into the animal through them, and the waste carbon dioxide can pass out. The group of animals to which they belong is called Nudibranchia'ta, in reference to the fact that their gills are naked. There is no indication of a rudimentary shell.

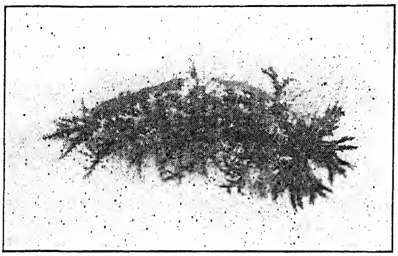


FIG. 115. Photograph of living nudibranch. (Natural size)

Definition of Gasteropoda (Gr. *gaster*, "stomach"; *pous* (*pod-*), "foot"). The class represented by the nudibranch, the slug, and the snails is given the name Gasterop'oda. The class name is only figuratively correct. The ventral surface, not the stomach, is modified to form a locomotor organ, the foot.

An important characteristic of the Gasteropoda is the unsymmetrical arrangement of organs. With the exception of the mouth and the opening of the mucus gland, all the openings of the body are on the right side, even in cases like the slug and nudibranch, where the general form of the body is bilaterally symmetrical. When a shell occurs it is composed of one piece, and the characteristic form is spiral. A shell-forming organ, the mantle, is usually present.

The body of a gasteropod is not divided into somites, but the head is slightly marked off from the rest of the animal, and is provided with eyes and nonjointed tentacles. A tongue-like organ bears a ribbon of minute teeth for tearing food.

The Squid. In the waters of the Grand Bank of Newfoundland and southward to Massachusetts the members of a species of squid, *Ommas'trephes illecebro'sus* (Fig. 116, *A*), occur in great numbers. They capture small fish and are themselves prey for cod and other large fish.

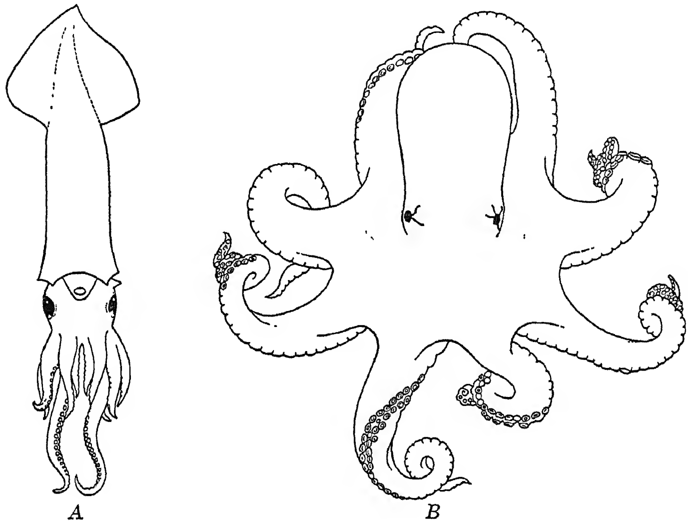


FIG. 116. Cephalopods. (Reduced)

A, a squid; *B*, an octopus. (From Van Cleave, courtesy of McGraw-Hill Book Company, Inc.)

The body of the squid is composed of a head and a slender, conical portion, the former having a pair of large, movable eyes (Fig. 116, *A*). Arising from the head region are ten long, club-shaped arms, corresponding to the foot of the Acephala and the Gasteropoda. Two of the arms are longer than the other eight, but all are provided on part of the inner surface with many sucking disks, adapted to holding the prey. The mouth has two horny jaws, resembling in appearance the bill of a parrot turned upside down. The tongue is adapted to rasping.

The conical portion of the body is the mantle, highly modified by the existence of strong, muscular bands. Part of the space within the muscular mantle is occupied by the internal organs inclosed in a body cavity. The remainder of the space, the mantle cavity itself, connects with the outside by a narrow opening, at either side of the neck, and also by the siphon. A pair of feather-shaped gills, one attached to either side of the body, lies in the mantle cavity. Imbedded in the tissue of the mantle, on the side opposite the surface shown in the figure, there is a long, pen-shaped structure composed of chitinous material. This represents the remains of the shell. The sexes are separate.

In locomotion the squid contracts and relaxes the circular muscles of the mantle, alternately decreasing and increasing the volume of the mantle cavity. During relaxation, water enters the mantle cavity at the sides by the neck, a valve in the siphon being closed; in contraction the valves at the side openings are closed and the water is discharged through the siphon. The siphon may be directed forward or backward at will. If it is bent in the direction of the arms, as it commonly is, the squid during strong contraction of the mantle darts backward "with the speed of an arrow," balanced and steered by the aid of the double mantle fin.

No more beautiful example of rapid color change can be witnessed than the one going on constantly in the skin of captive squids. From bluish white the color may change on the instant to mottled red or brown. The change may be sudden and complete, or the colors may fluctuate repeatedly from one shade to another and shimmer over the surface seemingly as rapidly as the controlling nerves can act. Observers who have been fortunate enough to come upon a "school" of squids in a harbor have been puzzled by the sudden disappearance of the animals. In times of danger the ability to change color to resemble the environment

must be of considerable value to them in escaping the notice of enemies, as well as useful in coming unseen into a school of small fish.

Another and still more effective means of escaping from the attack of a superior enemy is employed by the squid when driven to its last resource. It has in its body cavity a sac which secretes a black, inky fluid. A tube from the ink sac passes to the siphon, and in the moment of need the sac and the muscular mantle contract and force the black, confusing fluid into the water. The squid then has a chance to escape.

Along the coast of Newfoundland giant squids, belonging to a genus different from the one here described, are occasionally brought up from the deep sea and stranded on the shore. These monsters have a body about twenty feet long, and some of their arms measure more than thirty-five feet.

The Octopus. A close relative of the squid is the much-maligned octopus, or devilfish (Fig. 116, *B*). The body of the devilfish is sac-like and has but eight arms. Although the arms of these creatures may get to be several feet long, they are not nearly so dangerous to man as their appearance and stories about them might lead one to suppose.

The Chambered Nautilus. Almost the sole representative of a once numerous race living in the depths of the sea, is the chambered, or pearly, nautilus (*Nau'tilus pompil'ius*, Fig. 117). This species now has a restricted distribution in the vicinity of certain south Pacific islands, such as New Guinea and the Philippines. The nautilus lives on the bottom, usually in water from one hundred to seven hundred meters deep (three hundred and twenty-five to twenty-three hundred feet).

The shell of the nautilus is divided into compartments by cross partitions. Each of these compartments represents a

space in which the animal lived at successive stages in its growth. The chambers of the entire series are filled with air and are connected by a slender tube called the *siphuncle,* borne in a thin-walled, calcareous tube (Fig. 117, *11*).

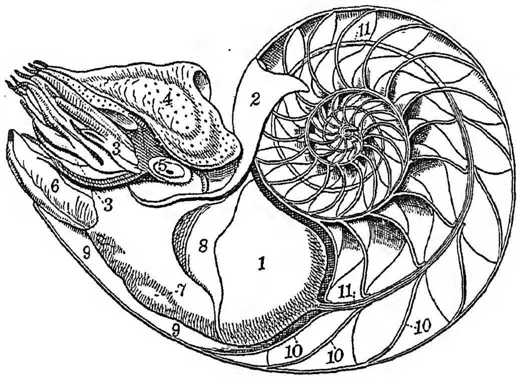


FIG. 117. Nautilus. (Reduced)

1, mantle; *2*, dorsal fold of mantle; *3*, tentacles; *4*, head-fold; *5*, eye; *6*, siphon; *7*, position of nidamental gland; *8*, shell-muscle; *9*, living chamber; *10*, partitions between chambers; *11*, siphuncle with tube. (After Ludwig) [1]

Oliver Wendell Holmes, in his poem "The Chambered Nautilus," thus refers to the phenomena of its growth:

Year after year beheld the silent toil
That spread his lustrous coil;
Still, as the spiral grew,
He left the past year's dwelling for the new,
Stole with soft step its shining archway through,
Built up its idle door,
Stretched in his last-found home, and knew the old no more.

Fossil Relatives of the Nautilus. Many millions of years ago, in the early history of the earth, the most ancient of the immediate ancestors of the nautilus lived. This form had a straight shell and is called *Orthoc'eras.*

[1] From Hertwig-Kingsley's *Manual of Zoology.*

From the study of fossils in later layers of the earth's crust we know that the group of nautiloids (nautilus-like animals) grew to be of large size, and their shells showed coiling more and more to the close coil of the present-day nautilus. All the hundreds of species of nautiloids, except four species of the nautilus, disappeared as living things ages before man came into existence upon the earth.

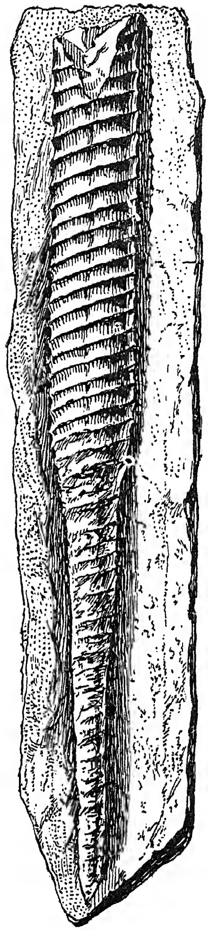


FIG. 118. Fossil *Orthoceras*. (Reduced)
After Blake

Definition of Cephalopoda (Gr. *kephale*, "head"; *pous* (*pod-*), "foot"). Because of their structural relationship, the squid, octopus, nautilus, and the fossil nautilus-like forms belong in a class together, the Cephalop'oda.

In this class the body has a distinct head. No part shows indications of being divided into somites. The head has two large eyes. The mouth is surrounded by divisions of the primitive foot, called arms or tentacles. These divisions of the foot either have sucking disks for holding on, or smooth surfaces which perform the same function. In the mouth there is a parrot-like beak and a rasping tongue. A shell-forming mantle either incloses the shell, as in the squid, or lies beneath it, as in the nautilus and in *Orthoceras*.

There are two gills in the mantle cavity in the squid, and four in the nautilus. A siphon is present in all the examples described. The sexes are separate.

Definition of Mollusca (Lat. *molluscus*, "soft"). The phylum Mollus'ca includes five classes. For the purpose of elementary study the most important of these are the Acephala, the Gasteropoda, and the Cephalopoda.

On the basis of the facts presented in this and the preceding chapter, we may formulate the following statement concerning the phylum. Mollusca are soft-bodied animals provided usually with a hard, calcareous, partly chitinous shell, which in some forms occurs on the exterior, and in others is partially or completely inclosed by a sheet of shell-forming muscular tissue, the mantle. The body proper is never divided into somites, and the appendages are never jointed.

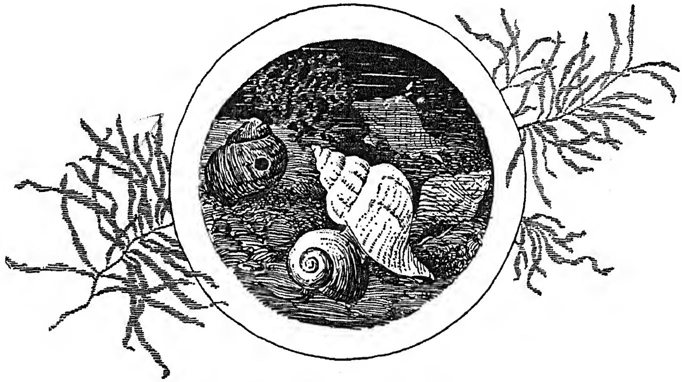


FIG. 119. Living oyster drill and periwinkle. ($\times \frac{2}{3}$)

CHAPTER XX

THE STARFISH AND SOME ALLIES: ECHINODERMA

Let the mere star-fish in his vault
  Crawl in a wash of weed, indeed,
Rose-jacynth to the finger-tips.

ROBERT BROWNING

THE STARFISHES

Habitat and Distribution. The purple starfish (*Aste'rias vulga'ris*, Fig. 120) is found most abundantly north of Cape Cod in tide-pools on rocky shores, and in deep water near the shore. It is only in the warmer season, however, that one may witness a scene like that portrayed in the illustration.

In addition to the species here mentioned there are several other species on the Atlantic coast. The Pacific coast is also well supplied with starfishes, some of which are considerably more than a foot in diameter. While most of the starfishes have only five arms, as pictured in Fig. 120, some have as many as twenty arms. When the winter storms come on, starfishes and many other tide-pool animals that are not fixed permanently migrate to the deeper water, in order to be in more protected places.

External Structure. Up to this chapter we have been giving our attention to animals that have a perfect, or slightly modified, bilateral symmetry. The starfish evidently has a plan of structure for which we must find some other name.

Instead of organs and structures being paired on the two sides of the body they are repeated around a central axis like the spokes of a wheel. In a specimen we observe five *arms* extending from a central region. The position of the

arms with reference to the central region, or *disk*, is practically the same as the position of radii in a circle. Hence we say that the starfish is *radially symmetrical*. We find it necessary also to change a few terms of location. In the picture of the tide-pool study we are looking down upon the *aboral* surface of the three starfishes. The opposite side has the mouth at the center, and for that reason is called the *oral* surface.

The aboral surface and part of the oral surface of *Asterias* is thickly set with hard, limy *spines* that arise from small plates of the same material just within the skin. Between the spines there are many short, soft projections — the *gills*. The spines of the oral surface are longer and more pointed than those of the aboral surface. By examining the aboral spines with a hand lens one can make out a circle of very minute structures surrounding the base. Each of these structures consists of a short stalk supporting two branches that open and close like nippers. These short stalks with their branches are called *pedicellariæ*. The body surface is kept clean by the pedicellariæ, and small animals are prevented from injuring the delicate gills by the protective action of these same organs.

Along the middle of the oral surface of each arm there is a groove which begins at the mouth and ends near the tip. The roof of the groove is formed by two series of flat, calcareous plates, set together like the rafters of a frame house. Between the plates four rows of slender, flexible *tube feet* (Fig. 121, *ab*) extend to the outside. The groove is called the ambulacral groove, because it protects the ambulacral organs (Lat. *ambulare*, "walk"). A few of the ambulacral organs (tube feet) near the tips of the arms are sense organs for "smelling" food. The remainder are the organs of locomotion. At the very end of each arm there is a small red *eye*, protected by a circle of spines.

Fig. 120. Tide-pool study of starfishes, East Point, Nahant, Massachusetts

One who has not observed a living starfish gets the idea from preserved specimens that the body is rigid, and that the plates of the skeleton make the arms inflexible. Such is not the case, for the body of the living animal is very supple.

The Water-Vascular System. On the aboral surface at one of the angles between the arms lies a small round disk usually of different color from the surrounding parts (Fig. 121, *m*; Fig. 122; Fig. 123). This is the *sieve plate,* sometimes known by the name *madreporic body.* The plate is perforated with fine holes, through which the seawater passes to the *stone canal* (Fig. 121, *s*; Fig. 123). Near the mouth the stone canal joins the *ring canal* (Fig. 121, *r*; Fig. 123), which in turn joins five *radial canals* (Fig. 121, *c*; Fig. 123) that extend through the middle of the roof of the ambulacral groove. Many short tubes branch off in pairs from the radial canals and join the tube feet. At the exposed end of a tube foot is a *sucking disk*; at the inner end is a bulb-shaped expansion, the *ampulla* (Fig. 121, *a*; Fig. 122; Fig. 123). From the sieve plate to the tube feet there is a continuous cavity, and because of the fact that water passes through the entire set of tubes it is called the *water-vascular system.*

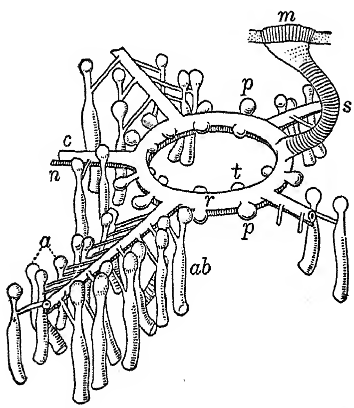


FIG. 121. Water-vascular system of starfish

a, ampullæ; *ab,* tube feet; *c,* radial canal; *m,* sieve plate; *n,* radial nerve; *p,* Polian vesicle; *r,* ring canal, with nerve ring beneath it; *s,* stone canal; *t,* Tiedemann's vesicle[1]

This system of tubes provides the starfish with its means of locomotion. The walls of the tube feet and ampullæ are

[1] From Hertwig-Kingsley's *Manual of Zoology.*

muscular. There are valves in the branches of the radial canals which lead to the tube feet. The entire system is filled with water which enters through the sieve plate. It is a well-known fact in physics that water is not readily compressible. This means that when the tubes are filled

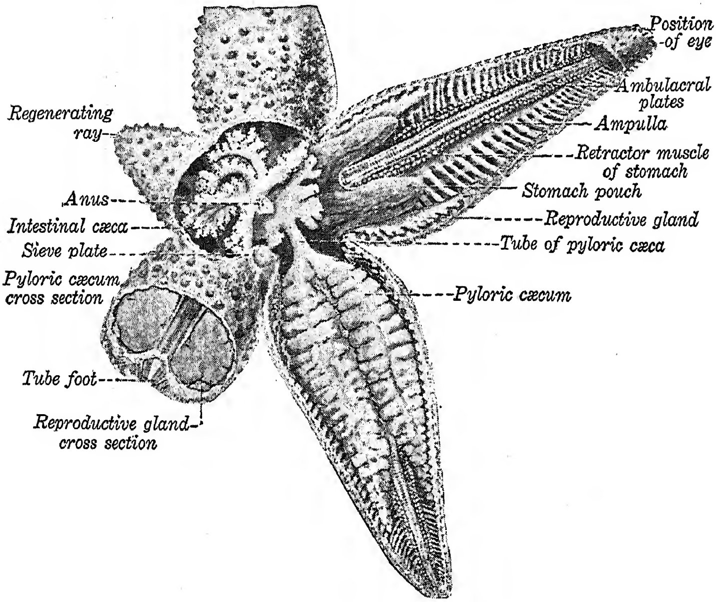


FIG. 122. Dissection of a starfish; aboral view. (Slightly reduced)

with water a contraction of the muscles in the ampullæ forces the water out into the tube feet. But since the tube feet are already filled with water, their muscles have to relax and permit the tubular part of the foot to stretch out longer in order to make room for the water entering under pressure from the ampullæ. When a whole group of tube feet are thus extended to full length, the disks on the ends of the feet are pressed against some object and by suction become attached.

The longitudinal muscle fibers in the tube feet then contract and drive the contained water back to the ampullæ. When the scores of tube feet in the advancing arms of a starfish contract they pull the body along and extend again to renew their hold. The arms themselves, meanwhile, are turned up a little on the tips and remain in a more or less set attitude. They may bend now and then to pass an obstruction. When it is necessary the

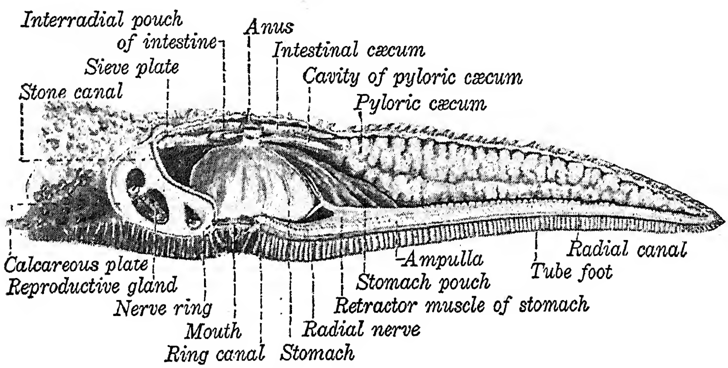


FIG. 123. Dissection of a starfish in oral to aboral section. (Slightly reduced)

animal becomes quite flexible. It can bend its arms and central disk and pass through seemingly impossible holes.

Digestive System. In the animals that have been studied previously, the digestive system has been a more or less complicated tube running straight through the body, or sometimes coiled. The digestive system in the starfish is entirely different (Fig. 123). There is a circular *mouth* which leads directly into a large *stomach* filling most of the space within the disk. Two short pouches, or pockets, extend from the stomach into each arm, thus giving more space for digestion. From its aboral end the stomach gives off five branches, one to each arm. Each of these

branches divides to form a pair of *pyloric cæca*. These are glands which aid in digestion. The *intestine*, which leads from the stomach to the aboral wall of the disk, is very small. It is too small to carry the undigested waste from the stomach and probably serves only to remove small quantities of waste. Any solid waste particles must pass through the mouth. A pair of small branched tubes, called the *intestinal cæca*, are attached to the intestine. Recent studies indicate that these cæca pulsate in the living starfish and probably serve as respiratory organs. The function of the pyloric cæca is digestive; they secrete a fluid analogous to the digestive fluid of the earthworm and the clam. The intestine ends at the *anus* (Figs. 122, 123), which lies near the center of the aboral surface.

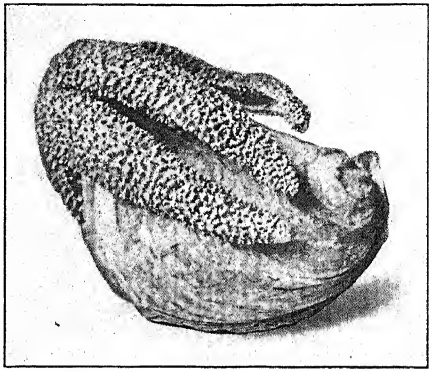


FIG. 124. Starfish devouring an oyster. (Reduced)

Photograph by Dr. H. M. Smith; courtesy United States Bureau of Fisheries

Asterias feeds on oysters, mussels, clams, and snails. Many fanciful theories have been proposed in the effort to explain how the starfish is able to get at the soft parts of animals with thick, heavy shells. By referring to Fig. 124 we can see the attitude of *Asterias* when it has captured an oyster. While crawling along the bottom the hungry starfish "smells" its prey by means of the tube feet at the tip of the arms. It then moves in the direction of the oyster or mussel and arches itself over the shell, touching the bottom all around with the tips of its arms. Next it turns the shell about until the hinge ligament rests on

the bottom and the free edges of the closed valves lie just beneath the captor's mouth. Then the starfish takes a firm hold on the bottom with the tube feet of the outer portion of its arms and simultaneously applies the suckers of the remaining tube feet to both valves of the mollusk.

Then the struggle begins. The mollusk has long before closed its valves tightly by means of its strong adductor muscles, and the only way the starfish can get at the soft parts is to force the valves open. This it does by a long-continued, steady pull on the surface of the valves, with two sets of tube feet drawing in opposite directions. The mollusk has great momentary strength, but it seems to be as difficult for it to keep up the strain as it is for a man to hold out his arm several minutes at a time. A single tube foot of the starfish is very weak, and the combined strength of all its tube feet measures less than the momentary strength of an oyster. Yet, even with the exertion of much less than its full strength, the starfish can open the valves in from fifteen to thirty minutes.

As soon as the valves are open a few millimeters the starfish contracts certain muscles in its body cavity, which bring the stomach down toward the oral surface and cause it to pass through the mouth opening, turning inside out on its way. The everted stomach is applied to the soft body of the mollusk, and digestion and absorption begin immediately. With slight variations this is the method which starfishes employ in opening and digesting oysters, snails, and other mollusks.

Starfishes are one of the most serious enemies of the oyster industry. Oyster fishermen drag mop-like tangles over the oyster beds. Starfishes become entangled in the fibers and are then brought to the surface and destroyed.

The Circulatory, Respiratory, and Excretory Systems. The circulatory system is too small to be indicated in drawings

on the scale of the dissection drawings. A very delicate *circular blood vessel* lies just below the ring canal of the water-vascular system and sends a branch into each arm below the radial canal. The body cavity is filled with a fluid similar to the blood, which is colorless. The system of blood vessels is not complete.

The body gets much of the oxygen it needs by way of the water-vascular system. The remainder comes in through the many short-branched *gills,* that cover the aboral surface between the spines like the pile of a soft mat. The gills are thin-walled tubes continuous with the body cavity through openings between the plates of the skeleton. Thus the fluid within the body cavity also fills the gills. In the gill this body fluid gives up its carbon dioxide to the water bathing the surface of the gills, while at the same time dissolved oxygen in the water passes through the delicate walls of the gills into the body fluid. As mentioned on page 227, the intestinal cæca also probably aid in respiration. Carbon dioxide passes out through the same organs which bring in the oxygen.

The diagram shows nine bulb-like organs on the outer margin of the ring canal. These are called the *Polian vesicles* (Fig. 121, *p*). The small glandular bodies, *Tiedemann's vesicles* (Fig. 121, *t*), which join the Polian vesicles are thought to have the function of producing amœbocytes, described on page 243. The cells on escaping into the body cavity consume the waste substance of metabolism and make their way through the body wall, perishing on the outside. *Asterias* has no definite organs of excretion, like kidneys or nephridia.

The Nervous System. If an observer takes a live starfish and parts the tube feet in an arm so that the animal's skin is exposed between the second and third of the four rows, he may see the dead-white, *radial nerve cord* extending along

just beneath the skin (Fig. 123). Fig. 121 shows the position of the nerve ring just beneath the ring canal. The circular blood-vessel lies between the ring canal and the nerve ring.

Reproduction and Development. The sexes of the starfishes are separate, but externally there is no difference between them. At the time the dissections were made for the drawings, the sexual glands in the specimens were small (Figs. 122, 123). As the first of June approaches, the ten sexual glands increase in size until they occupy all the available space in the body cavity of the arms. The *ovaries* of the females, when they contain ripe eggs, are bright orange in color; the *spermaries* of the males are a light cream color. From about the first to the middle of July, in the latitude of Boston, the sexual cells are sent out into the water through ten small holes on the aboral surface, two at each angle between the arms all around. The egg cells are fertilized by the sperm cells in the water, and within a few hours the young starfish in the *blastula* stage (see page 134) is swimming about at the surface by the aid of cilia. The most striking incident in the development of a starfish is the change that takes place after about three weeks of life as a free-swimming larva, when it settles toward the bottom and fastens temporarily to a seaweed.

Until this time the body of the larva has been bilaterally symmetrical, showing no evidence whatsoever of the radial arrangement characteristic of the adult. On the posterior region a star-shaped bud is formed, which becomes the adult starfish. As the bud grows it draws into itself the larva which gave rise to it. The starfish attains the stage of sexual maturity within a year.

Regeneration. It is not unusual to find in a lot of starfishes dredged from the bottom many specimens that have one or more arms shorter than the others (Fig. 122). This

means that some accident has befallen the irregular specimens, and that new arms are being formed to take the place of those that were lost. It has been found that a starfish deprived of all its arms will, under favorable circumstances, reform all five; but one that has suffered an injury as extensive as a cut through the entire disk probably never survives.

Serpent Stars and Basket Stars. The serpent stars and brittle stars (*Ophioder'ma*) have slender arms which are much more sharply marked off from the disk than are those of the common starfish. They are much less abundant than the common starfish, and being nocturnal in habits are rarely about in the daylight. The tube feet play no part in the locomotion of these animals, for the flexible arms move very readily and, clasping around objects, move the entire body much more rapidly than is possible to the common starfish. The food is chiefly small organisms and decaying organic matter. The basket star (*Gorgonoceph'alus*) lives in the depths of the ocean, where the pressure of the water is very great. The arms are very finely branched.

The Sea Lily

At the present day we find here and there in the comparatively warm, deep waters of the ocean, animals like that shown in Fig. 125 (*Pentacri'nus bla'kei*). In past geological eras the crinoids to which the sea lily belongs were very widely distributed, and fossil remains are abundant in many localities. Members of the genus *Pentacrinus* may be obtained by dredging in the deep waters about Porto Rico, and in the South Pacific and the Indian oceans.

The sea lily is a relative of the starfish and the basket star. The central disk and the radial arrangement of the arms make the resemblance striking. The sea lily is different from the starfish and the basket star in having a long

stalk which grows from the center of the aboral surface and sends root-like branches in among the rocks at the bottom. The mouth and the arms lie on the oral surface, which is uppermost. A water-vascular system is present, but it is of no service in locomotion. Movement in *Pentacrinus* is limited to the arms. Food is brought to the mouth by the wave-like action of cilia on the inner edge of all the arms.

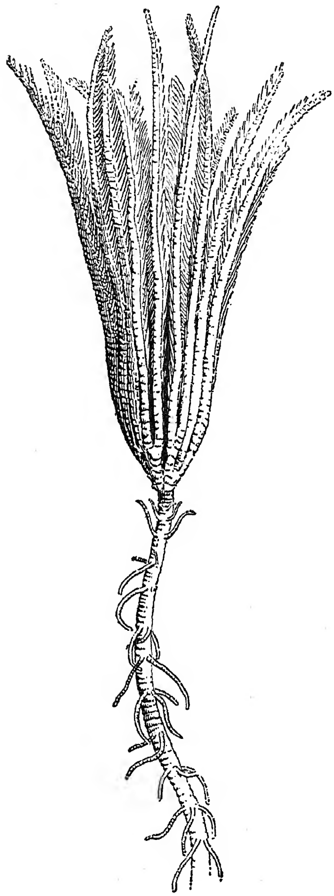


FIG. 125. Sea lily

From Report of H. M. S. *Challenger*

SEA URCHINS AND SAND DOLLARS

Sea urchins and sand dollars have no arms. The entire animal (Fig. 126) is contained in a hard shell which in the urchin is roughly hemispherical, and in the sand dollar is flat and disk-shaped as the name indicates. There is a large opening in the shell on the oral surface for the mouth, and fine double rows of small openings for the tube feet. The body is covered with movable spines. The sea urchins live chiefly on rocky ocean shores, where they feed upon seaweed and upon both living and dead animals. The sand dollars bury themselves in the sand and feed chiefly on the microscopic plants and animals living in the sand and mud.

Practically any tide pool along the north Atlantic coast that affords specimens of starfishes will harbor several sea urchins. The geographical distribution of the species *Strongylocentro'tus dröbachien'sis* (Fig. 126) is very wide. It is found on the coast of Great Britain and Norway, along the north Atlantic coast, and also on the north Pacific coast, — in all these regions from tidewater down to several hundred fathoms.

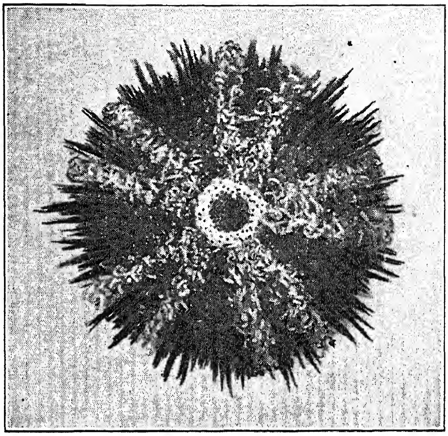


FIG. 126. Photograph of a sea urchin. (Slightly reduced)

If deprived of its spines a sea urchin suggests, as Professor W. F. Ganong has aptly said, "an old-fashioned door-knob," for it is flattened on its oral surface and curved above into a rounded dome. From the center of the dome one may trace downward twenty radiating rows of calcareous plates, fitting against one another closely. Five pairs of these plates radiating at equal angles have many fine holes for the tube feet; five other pairs of plates lie in the spaces between the regions of tube feet. All over the aboral surface and over most of the oral surface, the plates bear short, rounded knobs on which the spines fit and form a ball-and-socket joint. On each tube foot area at the point nearest the center of the aboral surface lies an eye; and between every two eyes there is an opening for the eggs or spermatozoa to emerge. A sieve plate lies in one of the spaces between two eyes. The mouth has five sharp teeth which meet together in a

point. The breathing organs are finely branched gills, located on the oral surface around the mouth.

It feeds on both animal and plant substance. Small animals are captured by the tube feet. The tube feet may be extended to a distance equal to half the diameter of the body; they affix by the sucking disk to some small creature and draw it to the mouth. All food is then ground into bits by the five sharp teeth before being swallowed.

A sea urchin, when taken from the water and placed in a person's hand, causes a gentle tickling of the skin. This it does with its movable spines. The spines may be of use as levers in pushing the body along, but locomotion in a definite direction is accomplished by the tube feet on the oral surface, aided by some of those on the aboral surface, all extending and contracting much as in the starfish. The uppermost tube feet are used as tentacles for feeling and it may be for smelling also.

In certain parts of our eastern coast members of the genus *Strongylocentrotus* live in cavities in the rock which are excavated by the animals themselves. A related species living on the coast of California burrows a hole in the solid rock deep enough to conceal itself entirely. No one knows positively how the burrowing is done. Probably three factors take part to a varying degree, — gnawing by the teeth, slow grinding by voluntary movement of the spines, and incessant slight turnings of the whole body by the waves.

The Sea Cucumber

Sea cucumbers of various species are found in every ocean. The species represented in Fig. 127 (*Cucuma'ria chronhjel'mi*) is found in Puget Sound, Washington. It lives on the bottom.

The animals are about four inches long. The body is cylin-

drical, but without calcareous plates that touch one another and keep the form constant. The only trace of a skeleton comparable to that of the sea urchin consists of scattered bits of calcareous secretions of definite form beneath the

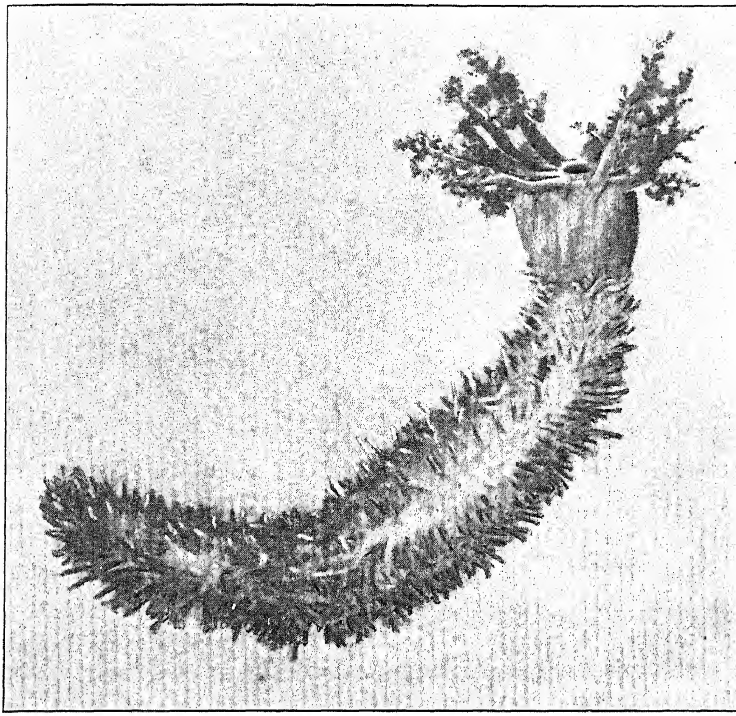


FIG. 127. Photograph of a living sea cucumber. (Natural size)

skin. Although the sea cucumber is radially symmetrical, having the five double rows of tube feet along the cylinder, we can speak of the anterior and posterior ends because the animal lies flat.

The anterior region is the oral region. At the center we observe the round mouth, about which are the ten branch-

ing tentacles. Internally there is a water-vascular system with a ring canal and radial canals. In respiration water is drawn into the intestine at the aboral end, and an exchange of gases takes place through internal gills that join the intestine.

The tentacles in the picture are not extended in the usual radial direction. The reason is that when photographed the animal was using its tentacles as well as its tube feet to crawl along the bottom of a dish of sea water. When the animal is at rest the tentacles are probably used to capture small animals and to pass them to the mouth.

Relatives of *Cucumaria* have been known by observers to disgorge the entire set of internal organs through the mouth opening. In captivity they appear to do this when placed in unfavorable situations. It is not so remarkable that they should lose their internal organs, as it is that they should regenerate them all again as perfect as ever. If sea cucumbers throw out their internal organs in nature, it would appear to be a very expensive process. Since they do perform this action, in nature as well as in captivity, there must be some reason for it. The only reason that suggests itself is based on the fact that fish prey upon sea cucumbers. The sea cucumber is a slow-moving animal, and once seen by a roving fish the chances of escape under ordinary circumstances would be few indeed. If the prospective victim when disturbed were to eject its internal organs into the water, the fish, true to the instinct of its kind, would gobble up the swiftly moving object, and probably go away satisfied.

Sea cucumbers are prepared and used as food by the Chinese, and it is reported that the Siwash Indians of the northwest of the United States eat them, and sea urchins also.

Definition of Echinoderma

Each of the five animals described in this chapter represents one of the five classes that make up the phylum Echinoder′ma (Gr. *echinos,* "hedgehog"; *derma,* "skin").

The most important characteristics of the phylum are the radial symmetry of the body; the occurrence of repeated divisions or organs of the body to the number of five, or in multiples of five; the existence of a water-vascular system; and the presence of limy plates in the skin, arranged as either a continuous shell or as scattered plates. No other phylum has parts occurring in fives, and none other has a water-vascular system.

CHAPTER XXI

AN EARTHWORM

I guess the pussy-willows now
Are creeping out on every bough
    Along the brook; and robins look
For early worms behind the plough.

HENRY VAN DYKE, An Angler's Wish

Habitat and Distribution. The animal (*Lumbri'cus terres'-tris*) which is the subject of this chapter is distributed widely throughout the world. This and very many other species live in the soil, where their burrows extend obliquely downward, sometimes many feet. One rather common species, *Helodri'lus fœ'tidus,* marked by red and dark bands of color, lives in manure heaps. When irritated it gives off an offensive odor, whence its specific name. The species most commonly used in laboratories is *Lumbricus terrestris.* It is found in small, cylindrical burrows, which it makes in the soil wherever it is not too dry or too sandy. In spite of the usual habit of living in the earth, these animals can live for many days in water. Representatives of the many species and the few genera of earthworms are found in practically all places from Arctic to Antarctic regions, including isolated oceanic islands.

External Structure. In external structure the body of an earthworm is very simple. The anterior end is slender and pointed when extended in life, and the posterior region is flattened above as well as below. The *somites* of the anterior region differ also from those in the posterior region in being longer. There is no head, no thorax, and no abdomen. There are no appendages except *bristles,* almost microscopic

in size, which occur in rows on the ventral surface of every somite except a few at the anterior end. The openings of the body are the *mouth* at the anterior end just beneath the *prostomium* (lip), the *anus* at the posterior end, and various openings on the ventral surface, which are connected with internal organs to be described later. An earthworm has no eyes, yet it knows of the existence of light, and shuns intense light; it has no ears, but it becomes aware of the approach of an enemy by the jar communicated through the soil. In a mature earthworm a thick band, consisting of the thickened body wall, is visible at about one third the length of the animal from the anterior end. This is called the *clitellum*.

All the many species of earthworms agree very closely in general structure and arrangement of the organs of the body. However, the following discussion is of the single species *Lumbricus terrestris*. Locations of the various organs will not agree exactly for any other species. Besides the more technical points of difference *Lumbricus terrestris* may be recognized as the species that has the tail very much flattened.

The internal anatomy of an earthworm seems, on reference to Fig. 128, to be very complicated, but each system of organs has well-defined uses.

Digestion. The first division of the digestive system of the earthworm is the *mouth* (Fig. 128), followed by the *pharynx*, the latter having a very thick muscular wall. The pharynx can be protruded slightly or retracted, and the cavity enlarged by strands of muscle fibers which extend to the body wall. Food, consisting of particles of leaves, animal tissues, and even soil, is drawn into the pharynx by the sucking action which takes place when the cavity of the pharynx is enlarged. The food passes directly through the *esophagus*. Before the ingested (swallowed) food reaches the *crop* the

secretion, and sometimes even hard particles from the *calciferous glands*, mixes with it. This probably serves to neutralize whatever acid may be present, and helps to maintain the contents of the esophagus in an alkaline condition. Thus the digestive fluid of the *intestine*, which is alkaline in chemical nature, can act without interference. The crop is a temporary reservoir for the food, and the *gizzard* is the only place in the entire digestive system adapted for dividing large particles of food into minute pieces. Earthworms are known to swallow small, rough pebbles, and even sharp pieces of glass, for the purpose of using them in the gizzard to grind into bits other particles which are swallowed as food. The strong muscles in the wall of the gizzard, by contracting, grind the contents together, and every particle is worn smaller.

The process of digestion in an earthworm begins when, on seizing food with its lip, the animal pours out a secretion from glands in the pharynx. Digestion continues as the food is being drawn into the pharynx, and while on its way through the esophagus.

The digestive fluid of the earthworm resembles the digestive fluid of the higher animals, in being capable of acting on the three important classes of organic foods.

Circulation. Whenever an animal body is too large or complicated for the food to reach all the cells directly, we find a circulatory system developed. The circulatory system of an earthworm is complete and rather complex. The *dorsal blood vessel* extends the length of the animal, along the middle, between the body wall and the alimentary canal. The blood flows toward the anterior region in somewhat regular "pulses," carried along by waves of muscular contraction in the wall of the blood vessel itself. Between the pharynx and the crop are situated five pairs of "hearts." These short tubes receive most of the blood that comes

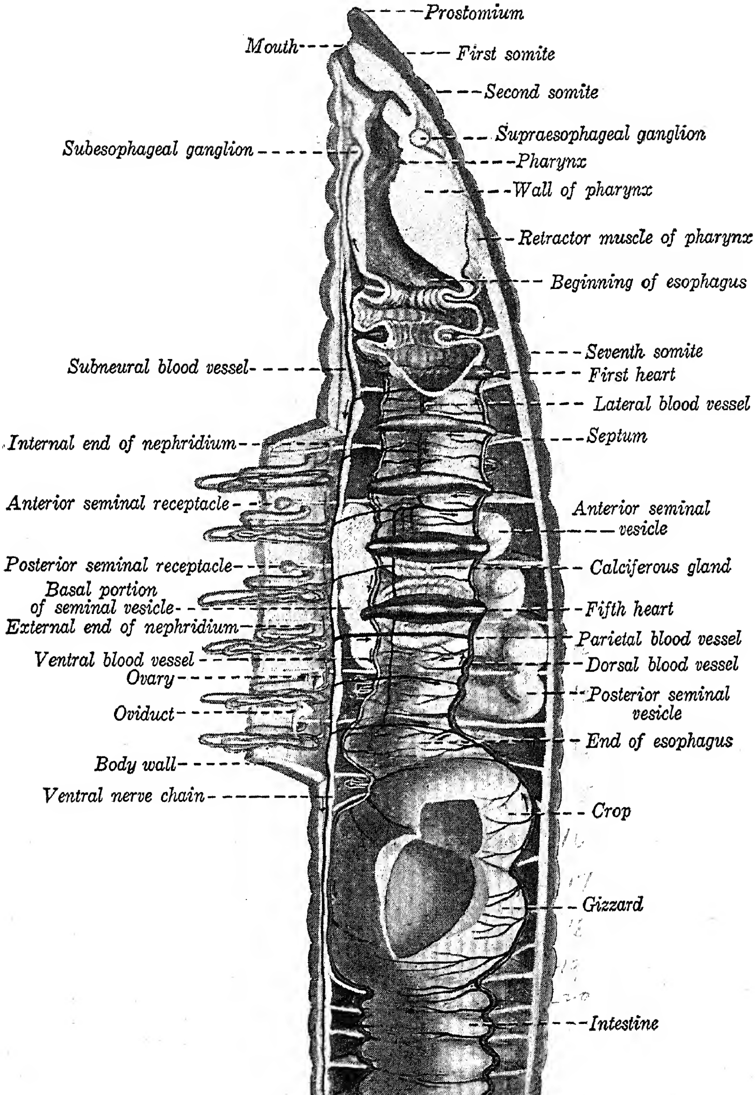


FIG. 128. Dissection of an earthworm, *Lumbricus terrestris*. (×4) Lateral blood vessels and connections. (After Johnston)

forward, take up the waves of contraction sent along the dorsal vessel, and force the blood into the *ventral blood vessel,* which carries it posteriorly in a regular flow. Below the ventral nerve chain is the *subneural blood vessel,* in which the blood probably flows backward. The *lateral blood vessel,* with its connections, is limited to the region anterior to the crop. *Capillaries* (fine blood vessels joining larger ones) branch in the wall of the intestine and connect in a very complicated fashion with all the large vessels. Absorbed food passes into the capillaries and is carried with the blood to the larger blood vessels, to be transported to all parts of the body. All about the intestine, in the hollow spaces of the somites, there is a large quantity of body-cavity fluid, which is very much like the blood in the vessels, except that it is colorless. It is thought that much of the absorbed food mixes with this fluid. The outcome is the same with food carried by the regular circulatory system and with that taken up by the body-cavity fluid. This food is carried by the blood and body-cavity fluid to all parts of the body, where it is assimilated by the tissues.

Respiration. The earthworm has neither gills, tracheæ, nor lungs; still it can breathe quite as perfectly as the animals which possess one or another of those organs. The outer skin of the earthworm is thin and moist, and just beneath it are capillaries. While in its burrow, or even in water, air comes in contact with the skin, and its most important element, oxygen, passes through and mixes with the blood. At the same time the blood in the capillaries gives up its carbon dioxide, which passes through the skin into the air.

Excretion. Carbon dioxide is given off only from the skin; water probably in part from the skin; uric acid and water are discharged from pairs of small funnel-shaped tubes in the lateral portions of the cavity of the somites. These

excretory organs are called *nephridia*. They correspond in function to the kidneys of the higher animals. Each nephridium opens into the cavity immediately anterior to the somite which contains the greater portion of the organ. The external opening of a nephridium is on the ventral surface.

The funnel-shaped end of a nephridium is lined with *cilia* (hair-like structures). The cilia beat inward and carry such liquid waste products as collect in the body cavity into the tube of the nephridium. Blood vessels, which break up into capillaries in the wall of the nephridium, also carry a certain amount of waste. The excess water and the nitrogenous waste in the blood are separated in these capillaries and go down the tube, to be discharged at the external opening. The body-cavity fluid is filled with small, free-moving cells, called *amœbocytes*. These amœbocytes are similar to the white corpuscles of our own blood. They have the power of changing their form quickly by extending irregular pointed processes from any part of the cell body. Owing to this power they can inclose any small particle of solid matter.

Nerve Control. In the preceding paragraphs we have been considering the stages of metabolism, without making any reference to the fact that no activity of internal or external organs could take place in the body of an earthworm if it were not for the controlling influence of the nervous system. Ingestion, digestion, absorption, circulation, respiration, and excretion constitute a chain of processes, largely because the nervous system, acting through the system of muscles, especially in the digestive and the circulatory systems, causes them to take place according to a definite plan. In order to understand how the nervous system of an earthworm acts, it will be necessary first to have some knowledge of the structure of its nervous tissue.

The general plan of the nervous system of an earthworm is similar to that of the grasshopper and the crayfish, but

less specialization is evident than in either of the other animals. The "brain" (*supraesophageal ganglion*, Fig. 128) is a simple, very small, bilobed ganglion, joined by connectives to a *subesophageal ganglion*; from the latter a pair of connectives extend along the ventral wall of the body cavity to the posterior end, with a ganglion in every somite. The brain and ventral nerve chain constitute the *central nervous*

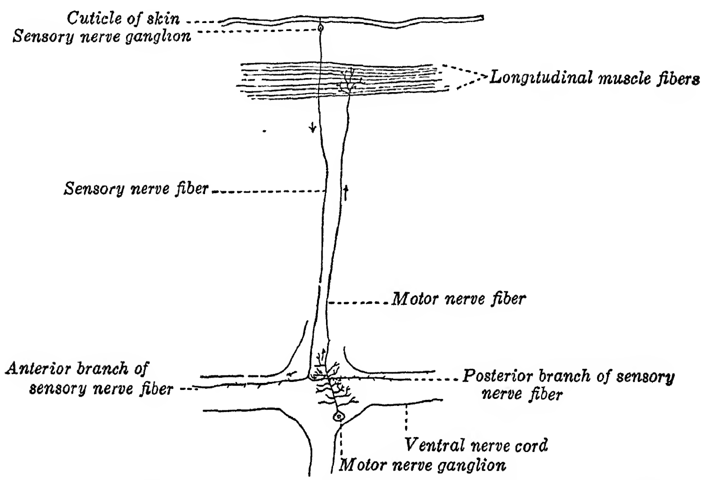


FIG. 129. Arrangement of nerve fibers for reflex action in the earthworm
Reconstructed from drawings by Havet

system. In each somite three pairs of *nerves* run out to the muscles of the body wall and the internal organs. The entire set of nerves leaving the central nervous system constitutes the *peripheral* (surface or outlying) *nervous system.*

If we were to trace one of the nerves outward from the central nervous system as it penetrates the muscular tissue, we should find that it divides into many very fine fibers. Certain fibers can be traced to the end as their fine branches become attached to a muscle fiber. The nerve fiber that is united with a muscle fiber (Fig. 129) is a slender portion

of a *nerve cell,* the nucleus of which is in the central nervous system. Nerve cells of this type are called *motor nerve cells.* Mingled with them is another type of nerve cell, which has its nucleus in a sense organ at or near the skin of the animal and with the terminal portion of its principal fiber extending into the central nervous system. Cells of this type are called *sensory nerve cells.*

Reflex Action. In case an object touches one of the fine sensory hairs on the skin of an earthworm, a message, or impulse, is sent along the sensory fiber to the ventral nerve chain. There the impulse is transferred to the motor nerve cells. When the impulse reaches the end of the motor fiber, the muscle fiber to which it is attached contracts. When many sensory nerve cells are stimulated in this way, many motor cells will carry out the transferred impulse, the muscles will contract, and the animal moves away. This kind of nerve action is called reflex action because, in a sense, the impulse is reflected back from the ventral nerve chain.

Reproduction. Every earthworm contains both *spermaries* and *ovaries.* As explained on page 206, animals which have the male and female glands in the same body are called hermaphrodites. There are two pairs of spermaries in an earthworm, hidden in the three pairs of *seminal vesicles,* indicated in Fig. 128. The single pair of ovaries is very small. Although each earthworm produces spermatozoa, or sperm, and eggs, the eggs of one individual are always fertilized by the sperm of another.

Reproduction takes place chiefly in the spring. On warm spring evenings the worms crawl from their burrows and lie stretched out on the surface of the ground with the tail still holding tight in the mouth of the burrow. While in this position two individuals may become paired in the act of copulation. The two worms have the ventral surfaces to-

gether for about one third of their length, with the "heads" pointing in opposite directions. This position brings each worm in a position such that the small openings which lead into sperm-receiving sacs (*seminal receptacles*) are in contact with the openings of the male reproductive organs of the other individual. Each worm expels a quantity of its sperm into the seminal receptacles of the other. In these receptacles the sperm is retained until the eggs are ready to be laid.

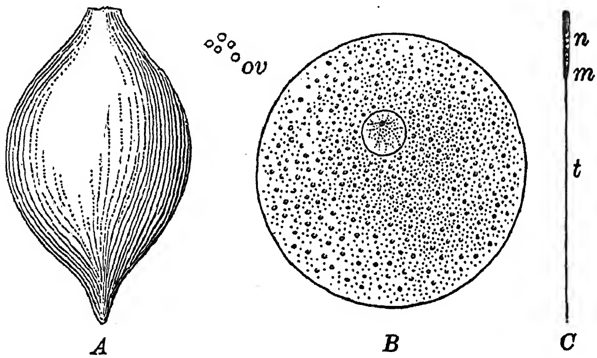


FIG. 130. Egg capsule, egg, and spermatozoon, of earthworm

A, egg capsule; *B*, egg with nucleus; *ov*, eggs; *C*, spermatozoon: *n*, nucleus; *m*, middle piece; *t*, tail [1]

The presence of the thick band, the *clitellum,* referred to on page 239, indicates that the individual is sexually mature. The clitellum is provided with glands on its ventral surface. Just preceding the time of egg-laying these glands secrete a thick mucus which forms a band about the clitellum. The band of mucus is then moved forward slowly. At the fourteenth somite the eggs are caught up from the *oviduct,* which forces them out, at the time the band, or capsule, passes. Farther forward the sperm that has been stored in the seminal receptacles is received into the capsule. At the anterior

[1] From Sedgwick and Wilson's *General Biology*.

end the capsule begins to draw together at the ends, and when this egg capsule (Fig. 130, *A*) has been pushed off it is a short, spindle-shaped, tough-coated sac, about as large as a grain of wheat. Inside the capsule each egg unites with a sperm in the act of fertilization.

Egg capsules are found buried in the soil and under stones and boards and other protected places. They are often mistaken for seeds of some plant, which accounts for their identity being unknown to most people.

Relation to Environment. We could find no animal better than an earthworm to show how an organism may be adapted to its environment. In the first place, the slender, rounded body with its pointed anterior end is the best possible form for movement through the soil, which is usually displaced by muscular effort. The appendages, which in the earthworm's relatives are never hard enough to be used for digging, are here only minute bristles. The animal is thus not impeded by useless organs. The smooth skin is thin, and since it is kept moist it serves as a breathing surface. Branched gills such as are developed on many relatives of the earthworm that live in the sea, would in an earthworm be not only superfluous but even much in the way.

It is a wonderful fact that the earthworm has no eyes and still is able to distinguish light from darkness; for, except in the time of a rainstorm or in case of disease, it never leaves its burrow in the daytime. Earthworms not only know the direction from which light comes but they crawl away from light of high intensity and crawl toward light of low intensity. In nature earthworms come out at night in the warm season, probably in response to the stimulus of a low intensity of light, but also for the purpose of obtaining food. They often leave the tail firmly anchored in the mouth of the burrow by means of the projecting bristles. When disturbed they spring back into the opening with incredible

speed. It is interesting to observe them with the help of a pocket flash light on a warm rainy night in spring or early summer.

When earthworms rest in the daytime, just below the mouth of their burrows, they do so probably as the result of at least four stimuli, — light, heat, fresh air, and moisture. If certain of these stimuli were taken away, or even changed in degree, the earthworm would undoubtedly move.

For example, if the moisture of the ground should become lessened by continued dry weather, the animal would have to forego the fresh air and retreat in order to prevent its skin from drying, which would shut off respiration altogether. If moisture becomes too great, as in a rainstorm, the burrows are filled with water, and most of the oxygen in the narrow, close quarters is driven out and the rest is soon used up. The earthworm is then compelled, if it has been resting near the surface, to leave its burrow and crawl about. This it may do in protected places without serious results, since the heat at such times cannot have its drying effect on the skin. When the storm is over, those that are not caught up by birds or trampled under foot by large animals can make their way into the soil again.

A food supply is assured to them, for besides the leaves which they drag into their burrows, they devour the soil itself, taking it into their mouths as they burrow along. Black soil called humus is made up of the usual soil minerals, mixed with a large amount of decaying vegetable matter and some animal matter. Completely decayed organic matter is that which has returned to its original inorganic, mineral state. The partially decayed organic matter can still be used as tissue-building and energy-producing food; it is this which the earthworms get in the soil they swallow.

It is one of the habits of earthworms to come to the surface at night to void the indigestible contents of the intestine. The coiled, worm-shaped "castings" are familiar to anyone who has noticed the ground where the grass is thin, even by the sides of much-used pavements in cities. The soil in the castings is usually brought from depths varying from a very few inches to as great a depth as five feet. Observations made by Darwin extended over a period of more than forty years. During that time he also collected facts from all parts of the world and published a book entitled *The Formation of Vegetable Mould through the Action of Worms*. His observations are extremely valuable to us now, for they show how small agencies acting over wide areas, through ages or even years of time, can yield tremendous results.

If every active earthworm voids its castings at the surface, fallen leaves, sticks, and other bits of organic objects will in a short time be covered with a thin coating of earth brought up from beneath. The acids present at all times in the soil attack and disintegrate the organic matter, thus enriching the soil with the minerals of which the growth of extensive crops may have deprived it. Darwin determined the rate at which objects once upon the surface gradually sink to lower depths. Layers of cinders, chalk, stone, and the like were strewn upon small fields, and trenches were dug from year to year to ascertain the progress of the earthworms' activity. In fields of ordinary fertility, having an average supply of worms, the amount of earth brought to the surface and spread out more or less evenly is one fifth of an inch a year. In the course of comparatively few years this is sufficient to conceal from sight objects of considerable size. Indeed, Darwin witnessed a sterile, stony field with flints "as large as a child's head" transformed into a fertile,

grass-covered pasture, "so that after thirty years (1871) a horse could gallop over the compact turf from one end of the field to the other, and not strike a single stone with its shoes. This was certainly the work of worms, for, though castings were not frequent for several years, yet some were thrown up month after month, and these gradually increased in numbers as the pasture improved."

Estimates which Darwin based on careful observations indicate that over fifty thousand earthworms find plenty of working room in an acre of ground, and that these bring to the surface annually from fourteen to eighteen tons of earth.

CHAPTER XXII

ALLIES OF THE EARTHWORMS: ANNELIDA

Sinuous, glittering worm of the sea,
Wondrous in sheen of ruby and green.

The Sandworm. One of the commonest of the animals living in the mud and sand at tide level in protected bays and inlets of all the oceans is the sandworm, known more definitely by its scientific name *Ne'reis vi'rens* (Fig. 131). It lives in burrows lined with a thick mucus. This unites the grains of sand into a tough, black tube. The depth of these burrows depends on the length of the animal, which is sometimes as great as two feet. Like earthworms, sandworms often rest with the head near the opening during the day. Sometimes at night they leave their burrows to swim at the surface. It is likely, however, that in most cases they do not withdraw the entire body from the burrow, but reach out in all directions for prey that comes near them. When driven from their burrows in the daytime they swim away, and at that time look very beautiful, as the couplet above suggests. *Nereis* has two horny jaws, sharp-pointed, and bending to meet at the tips. The jaws are concealed by the infolded pharynx when not in use. When about to seize its prey, which consists chiefly of small, living sea animals, the sandworm suddenly everts the pharynx, and the jaws, thus freed, at once spread horizontally and seize the victim.

Comparison of the external appearance of the sandworm with that of an earthworm brings out some points of difference, as well as some points of similarity. We observe the

same division into somites of approximately uniform structure throughout the body. Fully developed locomotor organs, and a distinct head with eyes and tactile sense organs, serve to adapt *Nereis* to its environment.

The Tube Worm. The name "tube worm" applies equally well to many genera of slender animals in the sea that live

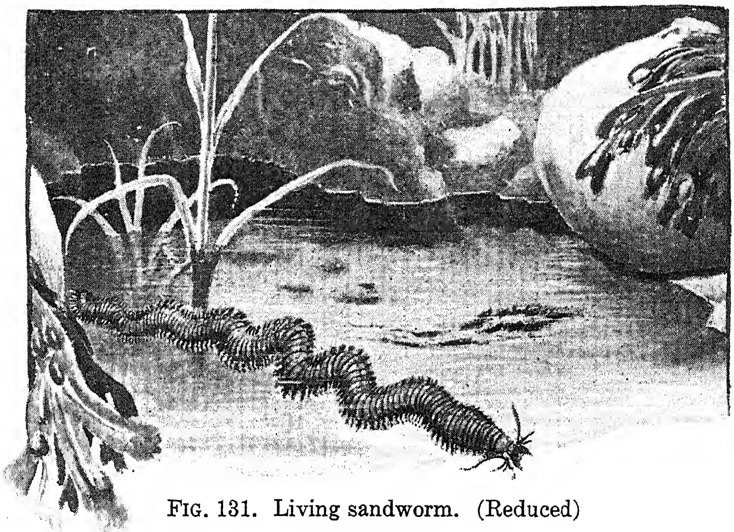


FIG. 131. Living sandworm. (Reduced)

continuously in tubes of mud, sand, or limy secretions. In *Amphitri'te orna'ta* (Fig. 132) the gills occur only at the anterior end, where they may obtain oxygen from the circulating water above the animal. To counterbalance the disadvantage of a fixed habitat, *Amphitrite* has many long tentacles which extend out over an area sometimes of three square feet. These tentacles are covered with scattered, fine bristles and with many cilia; the cilia are waving constantly toward the animal's mouth, carrying in the microscopic food present in the water. At the same time the bristles, aided by mucus which is secreted from glands on

the tentacles, catch up grains of sand. These are added to the little hummock that conceals the mouth of the tube.

The Leech. Most species of leeches are known to be temporary parasites on other animals. *Placobdel'la rugo'sa* (Fig. 133) feeds very commonly upon the blood of turtles. It is about two inches long and broader near the posterior end than elsewhere. The anterior and posterior sucking disks on the ventral surface are used for holding on to a support and for locomotion. *Placobdella* "loops" itself along, but it cannot swim, as some other species of leech can, although no leeches have appendages.

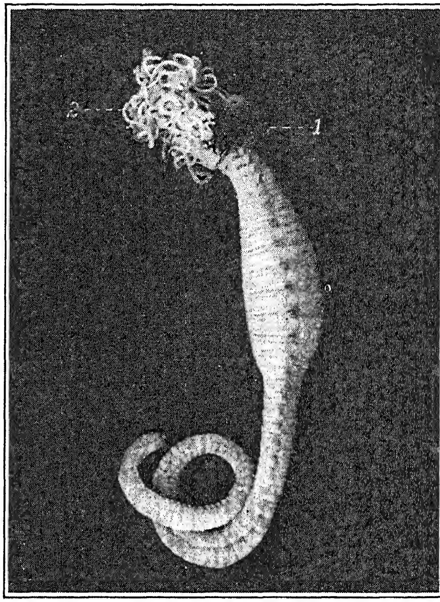


FIG. 132. Photograph of a tube worm. (Slightly reduced)

1, thread-like gills; *2*, tentacles

The body of a leech is divided into thirty-four somites, while these are superficially divided into two and sometimes more rings. Two eyes lie close together on the dorsal surface of the third somite. The mouth is on the ventral surface in the anterior sucking disk. The pharynx can be rolled out as in *Nereis*. The color of *Placobdella* is described by Professor Moore, of the University of Pennsylvania, as a "pepper-and-salt mixture of various light and dark browns, yellows, and greens." Around the margin are light-colored patches.

The digestive system of a leech secretes substances that prevent the blood used as food from clotting. This is interesting because after a leech is filled with blood it has enough food to last it for several months. When gorged with blood a leech is relatively inactive, staying in some secluded place until ready to seek new prey.

FIG. 133. Leech. (Slightly reduced)

Leeches of a different genus (*Pisci'cola*) frequently become parasitic on fishes. The horseleech (*Hæmop'is marmora'tis*) lives only part of the time in water and spends much time burrowing in the soil. This species is largely a scavenger, though it also feeds on snails, earthworms, and other small animals, and frequently becomes a bloodsucker. Some species in the tropical countries live on land permanently and are a great nuisance to pedestrians in the forests.

There are two different kinds of wounds made by leeches. Some leeches have three saw-like jaws which cut a Y-shaped opening in the skin. The jawless leeches have a conical lancing organ in the pharynx with which they pierce the skin.

Bloodsuckers feed upon human blood of bathers in fresh-water streams and lakes of many regions. In the not very distant past leeches were commonly used by physicians as a relief from many diseases. Blood-letting was then

considered good medical practice, and living leeches of a species known as the medicinal leech were regularly carried in stock by the apothecary shops.

Leeches are hermaphroditic. *Placobdella rugosa* carries its eggs in a gelatinous mass on the ventral surface. When the young hatch they live for several weeks attached by the posterior sucker to the parent, as shown in the picture.

Definition of Annelida (Lat. *annulus*, "ring"). The earthworm, sandworm, tube worm, and leech have certain characters in common. The body is divided into somites of nearly uniform shape, the characteristic form being a ring. From that resemblance the name of the phylum Annel′ida is derived. A conspicuous space, the body cavity, or cœlom, lies between the digestive tract and the body wall in every somite.

CHAPTER XXIII

ROUNDWORMS: NEMATHELMINTHES

Very close and diligent looking at living creatures, even through the best microscope, will leave room for new and contradictory discoveries.

GEORGE ELIOT

Ascaris. *As'caris lumbricoi'des* is often found as a parasite in the intestine of man. The body, which is cylindrical and tapering at both ends, is frequently over ten inches in length and in diameter as large as an ordinary lead pencil. The sexes are separate, and the male is always considerably smaller than the female. For a long time it was thought that this parasite was relatively harmless. Very recently it has been found that the young when taken into the digestive tract with food or water do not become established there at once as parasites. They first wander around, boring their way through various organs of the body. In young pigs they pierce the lungs in such numbers as to cause a disease resembling pneumonia. In the human being, *Ascaris* is especially likely to occur in small children. This is due to the fact that young children are not careful about what goes into their mouths. Food dropped onto polluted soil containing *Ascaris* eggs readily brings the eggs into a child's mouth. Whether we are interested in saving children or pigs from the ravages of *Ascaris* the same methods apply. Sanitary surroundings are not favorable for the worms.

The structure of *Ascaris* is very simple. The digestive tract runs as a straight tube throughout the length of the body. The cavity between the digestive tract and the body wall is filled with the coils of the reproductive organs.

Trichina. *Trichinel'la spira'lis* (Fig. 134, *1*) is one of the most dangerous of parasites. Like the tapeworm it requires two hosts to complete its development. The adult trichina may be found in the intestine of a pig, rat, or of man. The female trichina, about three millimeters (one eighth of an inch) long, bores into the wall of the intestine and brings forth her young alive. The young worms are carried by the blood and lymph streams to all parts of the body. When they reach muscle tissue they come to rest, and inclose themselves in a thick, tough membrane or cyst (Fig. 134, *2*), remaining encysted until the muscle is eaten by another animal. Then the cyst dissolves, permitting the young and still undeveloped trichinæ to grow and reach maturity in the intestine of the second host. If the first host is the pig, the second host may be the human being.

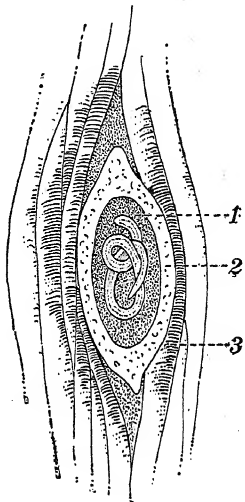


FIG. 134. Trichina. (Much enlarged)

1, parasite; *2*, membrane of cyst; *3*, muscle fiber of pig. (After Leuckart)

The danger to the human being comes while the young are making their way into the muscular tissue. The boring of thousands and sometimes millions of these larval parasites in the muscles disintegrates the tissue and causes a fever, which is very frequently fatal. A simple preventive remedy, which everyone should apply, is to see that all the pork that is eaten is thoroughly cooked. Human beings are infected less frequently by the trichina since the Bureau of Animal Industry of the United States Department of Agriculture established the system of inspecting packing houses (see page 266).

Hookworms. One of the most spectacular members of this group of roundworms is the hookworm. There are two species, known, respectively, as the Old World hookworm (*Ancylos'toma duodena'le*) and the New World hookworm (*Neca'tor america'nus*). The story of the conquest of the latter in the southern part of the United States is one of the brightest chapters in the history of preventive medicine in this country.

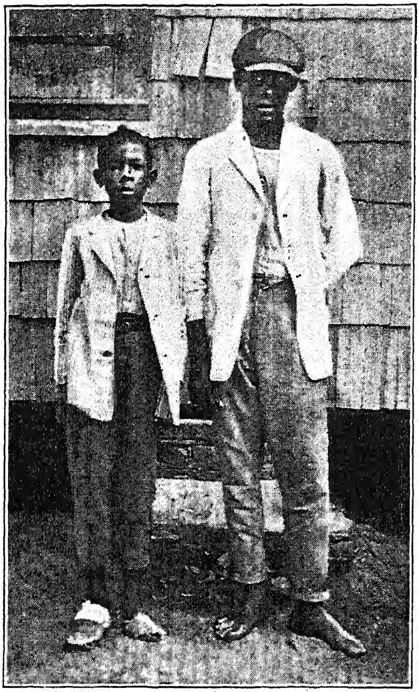


FIG. 135. The effects of hookworm

Two boys of about the same age, the one on the left suffering from hookworm. (Photograph by courtesy of the International Health Board)

The hookworms live in the large intestine of man. Though each hookworm is only about one-half inch long, when they are present in considerable numbers they produce serious diseased conditions (Fig. 135). These conditions are due chiefly to two causes. First, the mouth of the worm is provided with sharp tooth-like structures which pierce the wall of the intestine and cause constant loss of blood, upon which the worms feed. In the second place, they produce poisons, which seriously interfere with normal physical and mental development of the infected person. The patient becomes lazy and shiftless and, if a young person, fails to develop properly. A young

man of twenty may have the size and all the appearances of a child about twelve or fourteen years old. It was long thought that the shiftless and indolent "white trash" of the South were lazy by choice. During the present generation it was shown largely through the important works of Professor C. W. Stiles that they suffered from a disease produced by hookworms. Studies on the life history of the parasite and its methods of getting into the human body were carried on. It was found that only in unsanitary surroundings can the hookworm disease exist, for the young worms get into the soil only when it is polluted by the feces of a hookworm patient. From the polluted soil the young worms come into contact with bare hands and feet and bore their way into the skin. Here they find blood vessels or lymph spaces and are carried by the blood or lymph to the heart. From the heart the larvæ are pumped with the blood into the lungs. The minute worms by boring their way through the capillaries get into the air sacs of the lungs. They then crawl up the air passages into the mouth. The worms reach their final abode in the intestine only after completing this journey through the lungs. After being swallowed they pass in turn from the mouth into the esophagus and thence through the stomach into the intestine.

It was a triumph of medicine and of zoology when it was discovered that hookworm can be prevented by correcting unsanitary habits and living conditions, and educating the people in proper preventive measures. An equal triumph was the discovery of a simple cure for the disease. With the removal of the worms, the patient not only is saved from the disease but recovers his mental and physical development as well. The American Hookworm Commission, operating under the generous support of Mr. John D. Rockefeller, has carried on an extensive program of education in the South. In recent years Dr. M. C. Hall of the

Department of Agriculture in Washington discovered that carbon tetrachloride is a much more effective cure for hookworm patients than any drug previously used.

Hair Snakes. A myth believed at least for a time by most children in rural communities maintains that hair from a horse's tail, if allowed to stand in water, turns into a hair snake or hairworm. Many people think they have carried on a scientific experiment when they put a hair into a watering trough, and later find there a living, wriggling creature very much like a hair in appearance. The performer of such an experiment may not be aware that in the meantime a grasshopper or a cricket has fallen into the watering trough and from its body has crawled the long hair-like worm. The *Gor'dius,* or hair snake, lives, as an adult, free in watering troughs and streams. The female deposits long strings of eggs, which hatch into microscopic larvæ, each provided with a peculiar boring spine. By use of this spine the larva drills its way through the body wall of a cricket or a grasshopper and comes to lie in the body cavity. Here it completes its growth but is not able to reproduce unless the insect bearing it gets into water. Then the "snake" emerges ready to continue life as a free individual.

Definition of Nemathelminthes. All the roundworms whose bodies are not segmented but contain a body cavity belong to the phylum Nemathelmin'thes (Gr. *nema,* "thread"; *helmins,* "worm").

The roundworms include some of the most important enemies of man. As parasites they destroy his domestic animals and crops and many attack man directly. They produce disease and in some localities reduce the inhabitants to the lowest physical and economic standards of existence. Knowledge of these worms has been scanty until recently.

CHAPTER XXIV

THE PLANARIANS, FLUKES, AND TAPEWORMS: PLATHELMINTHES (FLATWORMS)

He prayeth best, who loveth best
All things both great and small;
For the dear God who loveth us,
He made and loveth all.

COLERIDGE, The Rime of the Ancient Mariner

A Planarian. On the lower surface of submerged stones, near the margin of ponds, there are many little black, or white, flatworms. The most of these belong to a genus called *Plana'ria.* Quite often a larger specimen (10 mm. to 15 mm.) is found among the others. This is most likely to belong to the species *Procot'yla fluviat'ilis* (Fig. 136). It is nearly colorless except for a clouded middle region. Upon examination with a simple lens an observer may distinguish the organs of the interior with remarkable clearness. The mouth is in the middle of the under surface. It is at the end of a short proboscis (the pharynx) which may be rolled inside out. Microscopic food entering the mouth may pass forward through a slender tube, and into all the many branches, or it may pass backward by two tubes and into their branches. Branches from the digestive system carry food directly to every part of the body. No separate circulatory system has been developed. At the anterior end beneath, there is a shallow sucker for holding on to stones

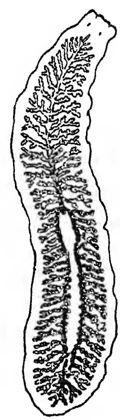


FIG. 136. A planarian. (×10)

or plants. Above there is a pair of small eyes of very simple structure. The body is not divided into somites. Each individual is hermaphroditic, but in many instances reproduction takes place asexually. In asexual reproduction the body becomes constricted and separates into two parts, each of which then grows the missing portion. Thus by fission two complete individuals result from the division of a single specimen. In addition to this normal means of asexual reproduction planarians have extreme powers of recovery from injury. Even a small fragment cut from the body of one of these worms has the ability to produce a complete new individual through the powers known as regeneration.

The class to which the planarians belong is called Turbella′ria (Lat. *turbo*, a "whirling," referring to the movement of water about the mouth). In all members of this class the body is covered with minute hair-like structures called cilia.

Parasitic Flatworms

Though planarians may on occasion live as parasites, there are two other classes of flatworms, the flukes, or trematodes, and the tapeworms, or cestodes, which are unable to live in any manner other than as parasites. It is not uncommon for these parasitic flatworms to produce disease in their hosts. Especially when they parasitize man or his domestic animals they may be of very great economic importance.

Trematodes. There are many kinds of trematodes, ranging in size from microscopic creatures barely visible to the naked eye to large, flat, leaf-like worms more than an inch long. Since they commonly live within other animals, they are but rarely seen except by students of zoology and medical men.

The Liver Fluke. In North America one of the most important trematodes from the economic point of view has

been the sheep liver fluke (*Fasci'ola hepat'ica*). This animal (Fig. 137) lives in the liver and bile ducts of sheep, producing a disease known as liver rot. This disease is not uniformly present over the country because of certain peculiarities in the life history of the worm. It was early noted that sheep grazing on lowlands were apt to contract this disease, while those kept in upland pastures away from water were free from attack. This is due to the fact that the parasite cannot be passed directly from one sheep to another. The adult trematode produces eggs which are carried from the body of the sheep along with the droppings. From each egg a microscopic larva is hatched. This larva dies unless it finds a certain kind of snail into whose body it can bore its way and carry on the next stage of its development. After two additional larval generations in the body of the snail, great numbers of minute tailed larvæ are produced and finally liberated into the water. These minute worms, after a period of free-swimming life, come to rest on blades of grass and other vegetation. Each forms a protective shell about itself and becomes an inactive cyst. If such a cyst is eaten by a grazing sheep, the young fluke is

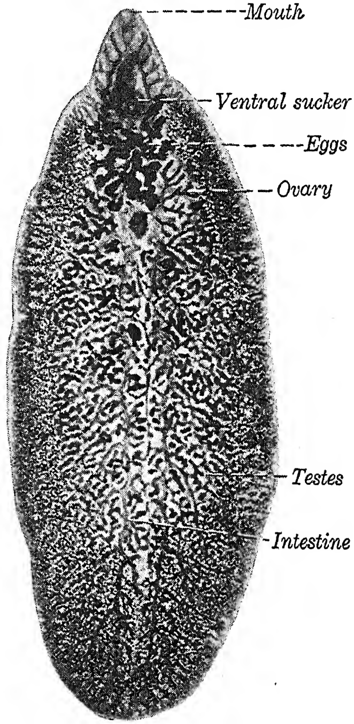


FIG. 137. Photograph of a sheep liver fluke stained for microscopic study. (×4)

set free from its cyst in the digestive tract and is given the chance to grow to maturity. All the higher trematodes pass through a life history similar to this. In each species a vertebrate serves as host to the adult worm, and the young worm cannot enter another vertebrate directly but must first undergo a series of stages at least one of which is passed in the body of a snail. Draining of swamps, fencing, and care in the selection of grazing range have done much to reduce the ravages of this parasite.

Human Flukes. In tropical countries, and especially in the Orient, trematodes become serious enemies of man. Blood flukes (*Schistoso'ma*) are especially common in Asia and in Africa. They are small worms, less than one-half inch long, living in the blood vessels of man. They cause disease by blocking the blood vessels. The eggs, which are provided with sharp spines, bore their way through the tissues. There are other flukes of grave importance in the Orient. A lung fluke (*Paragon'imus*) causes a disease very similar to tuberculosis. Liver flukes and various intestinal flukes also produce diseases in man.

The Simplest Flukes. The simplest of all the trematodes live on the body surface and gills of the lower vertebrates, especially of fish. Hooks and spines on the posterior end catch into the skin of the host and prevent the worm's being dislodged easily. Frequently muscular organs known as suckers also aid in this attachment. These external parasites, or ectoparasites as they are called, undergo direct sexual development. Nothing but accidental dislodgment would prevent the young from immediately becoming a parasite of the same individual host which sheltered its parent. There are no free larval stages and no complicated life history in these ectoparasitic trematodes.

Tapeworms. Tapeworms are likewise exclusively parasitic. There are but few species of animals from fish on up

the scale through man that are free from attack by the various species of these worms.

The Beef Tapeworm of Man. The best-known tapeworm is the one that is sometimes found to inhabit the intestine of man, *Tæ'nia sagina'ta* (Fig. 138). This parasite frequently grows to the length of many feet. The figure seems to show that the body is divided into somites, but these divisions are not considered true somites. The head of the animal is, except for the narrow neck behind it, the smallest portion of the body; the posterior portion is the oldest part of the parasite, except the head itself. New somite-like divisions of the body form just behind the head, and as they grow older and larger are pushed backward by newer ones. The tapeworm is an interesting example of a parasite that has become so completely dependent on its host that one of the most important systems of the body has totally disappeared, namely the digestive system. The parasite maintains its hold on the inner wall of the intestine by four sucking disks on the head; the body floats free in the intestine, and food can be absorbed from all sides.

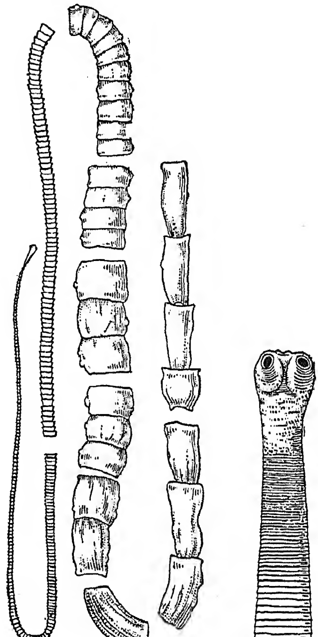


FIG. 138. Tapeworm. Left-hand drawing, reduced; right-hand drawing, enlarged

After Leuckart

Every tapeworm has in each division both eggs and spermatozoa. When the embryos reach a certain stage, a few terminal divisions of the adult separate from the rest,

and pass out with the undigested portion of the person's food. Sometimes the embryos, inclosed in their thick membranes, are swallowed by cattle while drinking at pools. In the intestine of the cattle the membrane of the embryo is dissolved, and the freed larva bores its way through the wall of the intestine, and finally comes to rest in the muscular tissue. It remains there until the muscle is consumed by man. If the larva has not been killed by cooking, it develops in man's intestine into the mature tapeworm.

Other Tapeworms of Man. Another species of tapeworm (*Tæ'nia so'lium*) found in human beings comes from uncooked pork. Tapeworms are not necessarily fatal. The annoyance is considerable, however, until, by a period of fasting and medical treatment, the head of the parasite is removed from the intestine. The fish tapeworm of man is of restricted distribution, for it occurs in only a few localities near lakes where the inhabitants eat raw fish containing the living larvæ.

Prevention. Government inspection of meat in the packing houses has been an important agency in reducing the numbers of cases of beef tapeworm and pork tapeworm in man, for these worms get into the human body only when raw or partially cooked beef or pork containing living larvæ is eaten. Government inspectors examine the hogs and cattle in the packing houses which are under federal inspection, and if larval tapeworms are found the animal is not sold for meat.

The class to which the tapeworms belong is called Cesto'da (Gr. *kestos*, "girdle"; *eidos*, "form").

Definition of Plathelminthes (Gr. *platys*, "flat"; *helmins*, "worm"). The members of the phylum Plathelmin'thes are worms with flattened bodies that are not divided into somites. Almost all the species are hermaphroditic. All the flatworms lack a body cavity.

CHAPTER XXV

THE FRESH-WATER POLYP AND SOME ALLIES: CŒLENTERATA

To-day the many-hued anemone
Waving, expands within the rock-pools green,
And swift, transparent creatures of the sea
Dart throu' the feathery sea-fronds scarcely seen.

SIR LEWIS MORRIS

The Fresh-Water Polyp. There are several species of fresh-water polyps (Fig. 139). These are so small that the casual observer would seldom be aware of their existence, even though they were abundant in his aquarium. Two common species are *Hy'dra viridis'sima,* the green hydra, and *Hydra oligac'tis,* the brown hydra.

The green hydra lives among green fresh-water plants in places where there is abundant sunlight. At rest, it holds to a plant with its aboral surface, the remainder of the body floating outward or downward. The body, which is cylindrical in form, is about 3 mm. ($\frac{1}{8}$ in.) long and .4 mm. ($\frac{1}{60}$ in.) in diameter. A little practice will enable a person to distinguish one in an aquarium, for specimens frequently leave the green plants and crawl up the side of the glass nearest the light. They can move either by a slow, creeping movement on the aboral surface, or by the process of "looping," like a measuring worm. Hydras exist for a long time in an aquarium, provided there is an abundance of their food animals, which are usually small Crustacea.

The number of tentacles which a specimen of the green hydra may have depends upon its size, and also upon its age.

The small individuals are generally the youngest; these have four tentacles. The larger, older ones gain in the number of tentacles, up to the extreme number of eleven; but there is a greater percentage of individuals with six tentacles than with any other number.

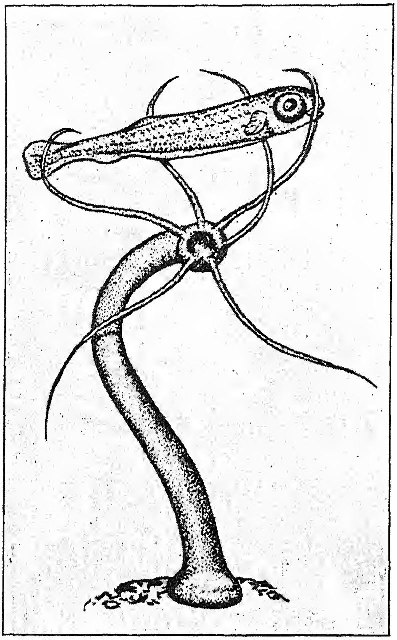


FIG. 139. Hydra capturing a fish. (Enlarged)

Courtesy of the American Museum of Natural History

Internally, the hydra is the simplest animal we have studied. There is no distinct alimentary canal separate from a body cavity. Those animals that do not have a body cavity and an alimentary canal have but one cavity to take their place; this cavity is called the gastrovascular cavity, because in the same space food is digested and carried about. The fact that food and oxygen can pass into any portion of the body, even into hollow tentacles, accounts for the absence of a circulatory system, which usually serves the purpose of transporting oxygen, digested food, and also waste products from part to part in the animal body. The mouth (Fig. 140) opens into a cylindrical cavity with no indication of gullet. The cavity extends by slender tubes out into each tentacle, and in all parts only two layers of cells separate it from the water outside. The inner one of these two layers is the

endoderm, and the outer one, the ectoderm. Cells of the endoderm secrete fluid for digesting food, and even take up small particles of food, digesting them inside the cell substance. The ectodermal cells are modified into nettle cells, nerve cells, muscle cells, and general surface cells.

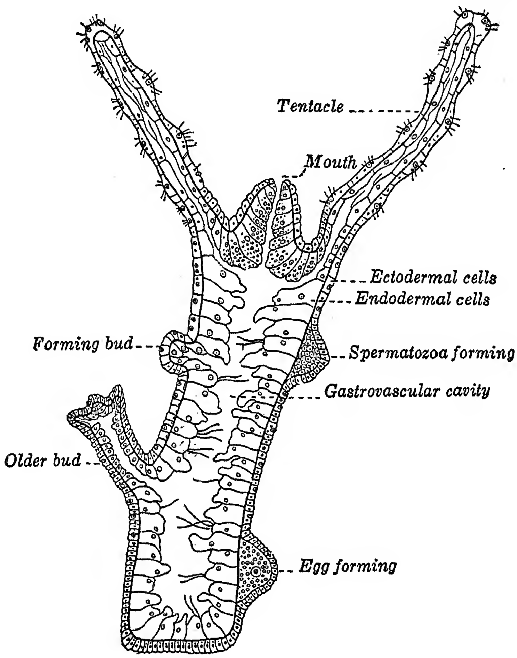


FIG. 140. Longitudinal section of a Hydra. (Much enlarged to show structure) [1]

In capturing food (Fig. 139) the hydra makes use of very effective organs called *nettling cells* (Fig. 141). These organs are found only in the phylum to which the hydra belongs. By the aid of the nettling cells the prey is paralyzed or killed, and then the tentacles push it into the mouth. The nettling cells, which are of several different sizes, are

[1] Modified from Parker's *Elementary Biology*.

found both on the tentacles and on the body. Each cell (Fig. 141) consists of a minute microscopic sac within which is coiled a hollow thread. A small hair-like projection from the surface of the body near each nettling cell may control the action of the cell. When this hair is touched the coiled thread within the sac is shot out with force sufficient to pierce the shell of a small crustacean. The thread carries with it a fluid which paralyzes the prey.

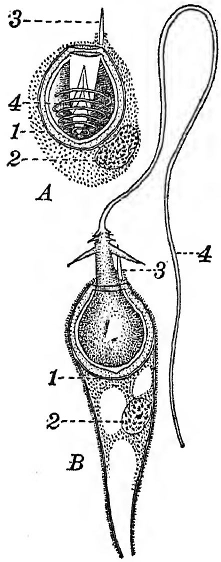


FIG. 141. Nettle cells of a hydra. (Much enlarged)

A, nettle cell, with undischarged nettling capsule; *B*, nettle cell, with discharged nettling capsule; *1*, nettling capsule; *2*, nucleus of nettle cell; *3*, bristle of nettle cell; *4*, hollow filament of nettling capsule. (After Schneider)

Reproduction may take place by the sexual method, or by budding. Eggs (Fig. 140) are developed in the ectoderm near the aboral end. In the same individual spermatozoa (Fig. 140) are formed in the ectoderm nearer the oral end, and these on escaping fertilize the eggs, which remain in the ectoderm for some time as embryos. Then the embryos separate from the parent, and after swimming about for a variable period develop into organisms like the parent. Nonsexual reproduction is the more frequent method, however. Buds involving both ectoderm and endoderm form on the side of the body; four tentacles appear, the mouth forms, and the base of the bud constricts, setting the young hydra free to begin its own career. This asexual method is so effective that hydras become extremely numerous in some lakes. In fish hatcheries hydras sometimes become so abundant as to destroy the very young fishes (Fig. 139).

Hydroids and Medusæ. There is a large group of animals closely allied to the hydra, that live in the sea. A portion of one of them, *Bougainvil'lia frutico'sa,* is shown in Fig. 142. It looks very much like a plant, owing to its habit of branching. The colony may contain many polyps, each of which is connected indirectly with every other by means of the continuous body wall.

There are two different kinds of individuals in such a colony. One of these very closely resembles the Hydra. The other is a minute jellyfish, or medusa, which is formed by the colony, but later separates from the colony and leads an independent, free-swimming existence. At the base of the colony, root-like branches from a stem-like structure cling to floating timbers or buoys. Although the colony reaches the height of two inches, the individual polyps are microscopic in size. Each polyp has about fourteen tentacles amply provided with nettling capsules, which aid in capturing small pelagic animals. The mouth is at the center of the circle of tentacles (Fig. 142, *1*); it opens directly into the gastrovascular cavity. As the branches are terminated by feeding polyps,

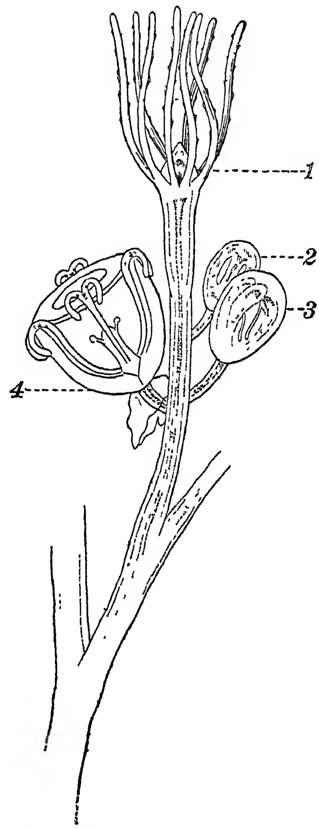


FIG. 142. Hydroid. (Much enlarged)

1, tentacles; *2*, *3*, *4*, stages in the formation of medusa. (After Allman)

the cells of the branches are probably supplied with food by the polyps nearest at hand.

Reproduction in *Bougainvillia* may be a mere increase in the number of polyps by a process of budding similar to that described for the hydra. Occasionally, however, a bud develops into a structure totally different from an ordinary polyp, and after a series of stages, indicated in Fig. 142, *2*, *3*, *4*, finally becomes separated from the colony and floats away as a free-swimming individual (Fig. 143). This is called the *medusa* stage of the animal. The medusa is shaped something like an umbrella.

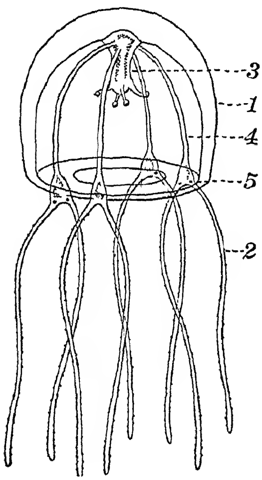


FIG. 143. Medusa. (Much enlarged)

1, bell; *2*, tentacle; *3*, manubrium; *4*, radial tubes; *5*, sense organs. (After Allman)

The structure hanging within the cavity of the bell is called the *manubrium*. The mouth is located at the end of the manubrium (Fig. 143, *3*). The gastrovascular cavity sends out four slender tubes (Fig. 143, *4*) radially to the margin of the body, where a circular canal joins them. Tentacles (Fig. 143, *2*) stream downward from the margin, and at their bases are minute sense organs (Fig. 143, *5*).

There are male and female medusæ. The ovaries and the spermaries of *Bougainvillia* are located on the manubrium. When the eggs and spermatozoa are ripe, they pass out through the mouth, and fertilization takes place in the water outside. The embryo swims about for a time and then settles to some fixed or floating object, attaches itself, and soon another colony of the hydroid (hydra-like) stage is developed by budding. The life history of *Bougainvillia* illustrates *alternation of generations*. The fixed, colonial,

nonsexual hydroid stage alternates with the free-swimming, single, sexual medusa stage, and together they complete the life cycle.

Definition of Hydrozoa (Gr. *Hydra*, the fabulous monster; *zoa*, "animals"). The class Hydrozo′a includes the genus *Hydra* and many thousands of species of hydroids. The life history described for *Bougainvillia* does not apply to all species of hydroids, but it is as characteristic as any. Hydrozoa are small animals occurring singly and in colonies. There is but one cavity in the body, and that is continuous with the mouth opening. There are but two layers of cells, the ectoderm and the endoderm. In some members of the class the two layers are separated by a jelly-like mass secreted by the cells. The body is radially symmetrical. Tentacles with nettling capsules in their ectodermal cells are the organs of offense and defense.

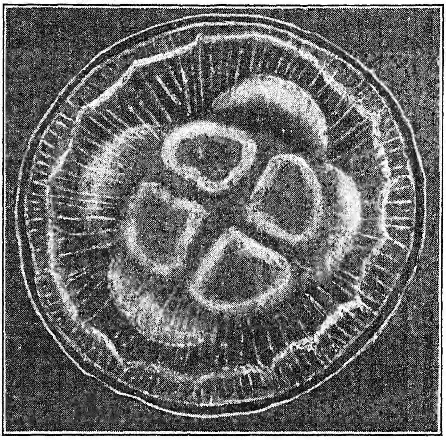


FIG. 144. Photograph of a jellyfish. (Reduced)

Larger Jellyfishes. Although the name "jellyfish" is sometimes applied to the medusæ of the class Hydrozoa, it is more commonly given to the larger, saucer-shaped, or bell-shaped, animals that swim at or near the surface in harbors and bays of all oceans. The species most frequently found from Massachusetts southward is *Aure′lia flavid′ula* (Fig. 144). This jellyfish reaches the diameter of fifteen inches.

In various details of structure *Aurelia* resembles the medusa of certain hydroids, and also the sea anemone, the coral polyp, and the fresh-water polyp. The mouth opens at the center of the under-surface into a large cavity which branches freely into many tubes running to the circumference, where they join the circular canal. Between the ectoderm covering the body, and the endoderm lining the gastrovascular cavity, is a great mass of jelly secreted by the cells of the two layers. Hanging from about the mouth are four broad ribbon-like appendages called "lips." These and the delicate fringe of tentacles at the rim of the bell are covered with nettle cells.

A very noticeable detail of structure that one observes in watching these animals in the water, especially in the late summer, is the set of four partial rings about the center, yellowish in color in the males and reddish in the females. These rings are the gonads. They are sacs which contain the eggs or sperm until these cells are ready to be discharged. On the rim of the bell, at eight equidistant points, are small, rounded balancing organs. The most important muscle is a circular band near the rim. The nerve cells are grouped near the sense organs, and connect the latter with the muscle band. When the circular muscle contracts, the bell becomes more convex, and the resulting action of the water in the hollow of the bell against the water that is outside sends the animal along in a slow, periodic, pulsating movement.

The development of *Aurelia* is very different from that of the hydroids. The simple, free-swimming larva of *Aurelia* sinks to the bottom, attaches itself to some fixed object, and takes on a form resembling *Hydra*. The formation of circular grooves below the tentacles develops a series of saucer-like divisions, one within another. These separate and, swimming away with the convex, aboral surface upper-

most, grow into the adult form. The fixed stage is comparable with the hydroid generation of Hydrozoa.

Aurelia is but slightly more dense than the sea water itself. According to one authority there is less than one eighth of 1 per cent of protein material present. Thus over 99 per cent is water. The small amount of protein material in the body of *Aurelia* makes it very unlikely that many animals depend on them for food. After a storm in summer great numbers of aureliæ may be found on the shore. In a few hours only scattered films are left on the sand to show where the animals lay. The destruction of many aureliæ is to be expected because of their general helplessness, but annihilation of the species is prevented by the enormous number of young produced.

Aurelia and its giant relative *Cya'nea,* which sometimes grows to a diameter of eight feet, might threaten to fill the ocean with their bodies, were it not for the fact that neither lives over the winter. The young start their development in the autumn and complete it in the spring. It is a self-evident fact, in this instance at least, that death is a benefit, not only to all other forms of sea life, but even to the race of *Aurelia* itself. The adults swallow everything that can be taken into the mouth, but probably their most abundant food is small pelagic Crustacea similar to *Cyclops* (Fig. 92).

The class of which *Aurelia flavidula* is a representative is called Scyphozo'a (Gr. *skyphos,* "cup"; *zoa,* "animals").

The Sea Anemone. The best-known sea anemone of the North Atlantic coast is *Metrid'ium margina'tum* (Figs. 145, 146). The picture of the tide pool shows sea anemones in various attitudes. *Metridium* has the power of moving by creeping along on its base, but it seldom changes its place of attachment, even in the coldest weather.

The form of *Metridium* is nearly cylindrical. The oral end of the column-shaped body, or polyp, expands into a

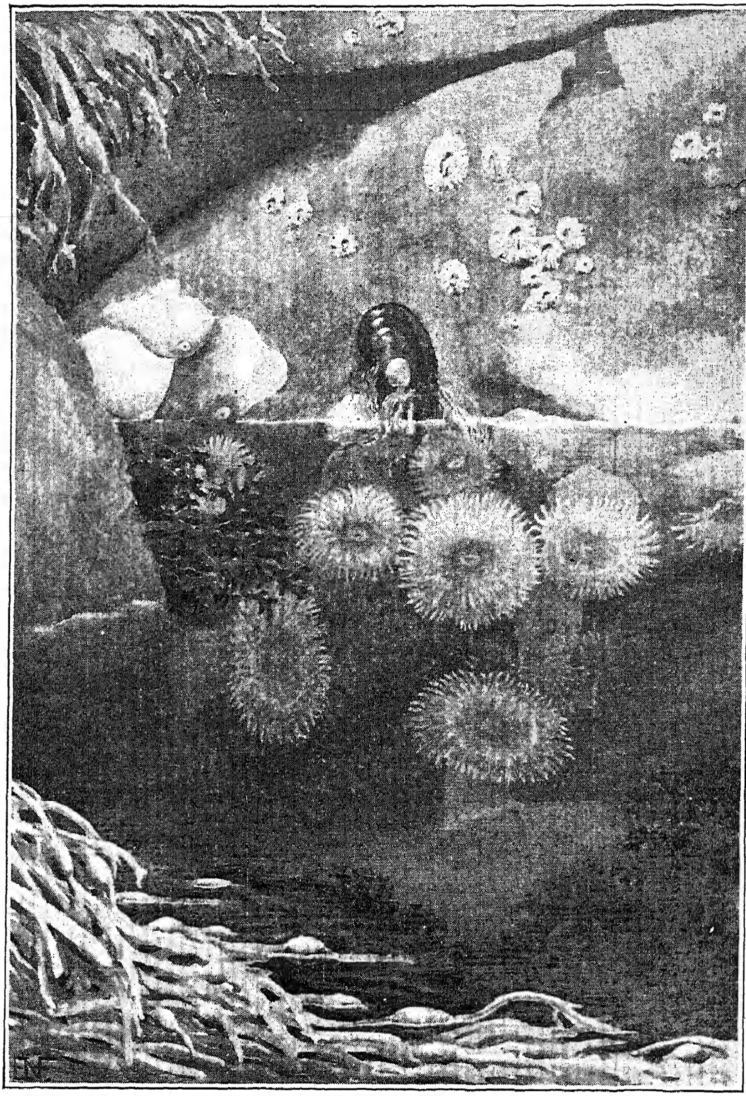


FIG. 145. Tide-pool study of sea anemones, East Point, Nahant, Massachusetts

crown of many small, slender tentacles. At the middle of the oral surface is the mouth, which is a slit-like opening. The skin of the body is soft, but it is rather tough.

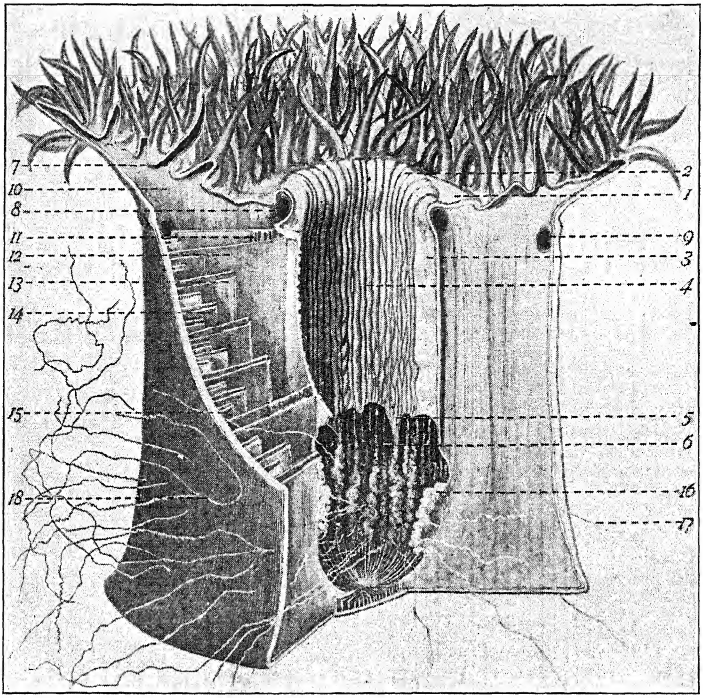


FIG. 146. Dissection of a sea anemone. (Natural size)

1, zone between tentacles and mouth; *2*, lip; *3*, ciliated groove in gullet; *4*, gullet; *5*, inner end of gullet; *6*, edge of mesentery; *7*, cavity within tentacle; *8*, *9*, internal openings between chambers; *10*, primary mesentery; *11*, muscle of primary mesentery; *12*, abnormal tertiary mesentery; *13*, secondary mesentery; *14*, tertiary mesentery; *15*, quaternary mesentery; *16*, gonad; *17*, mesenterial filament; *18*, opening for mesenterial filament

The mouth opens to receive the food, which is sometimes quite large, and the *gullet* (Fig. 146, *4*) passes it down by ciliary action aided by muscular activity in the gullet-wall. At the inner end (Fig. 146, *5*) of the gullet, food passes into

a large space which extends radially between *mesenteries* (partitions) (Fig. 146, *12, 13*) to the body wall.

There are usually six pairs of principal mesenteries in *Metridium marginatum.* They are thin, radial partitions extending from the gullet outward and downward to the body wall. These six pairs are called the *primary* mesenteries (Fig. 146, *10, 11*). In the arcs between the sets of primary mesenteries there are *secondary* mesenteries, also in pairs (Fig. 146, *13*), arising from the body wall and extending part way toward the gullet. The *tertiary* mesenteries (Fig. 146, *14*) and the *quaternary* mesenteries (Fig. 146, *15*) extend shorter distances into the gastrovascular cavity, but all unite with the body wall of the oral and the aboral ends, and in the latter place meet at the center. Occasionally a mesentery grows beyond the usual width and becomes attached to the gullet, as in Fig. 146, *12*.

At the free edge of the widest mesenteries below the end of the gullet there are to be found coiled masses which are composed chiefly of mesenterial filaments (Fig. 146, *17, 18*). These filaments are thickly set with microscopic nettle cells, like those shown in Fig. 141. When the animal is disturbed greatly, the mesenterial filaments stream out through the mouth and through small invisible openings in the body wall. It is likely that the most frequent use of the mesenterial filaments is for defense.

The Coral Polyp. The only coral polyp of the North Atlantic coast is *Astran'gia da'næ* (Fig. 147). It occurs in colonies of many individuals and incrusts rocks or pebbles in shallow water near the shore line from Massachusetts to North Carolina.

A polyp of *Astrangia* is about one eighth of an inch in diameter and of variable length. It bears a very obvious resemblance to a sea anemone. The columnar form, the flattened aboral surface resting on a support, and the oral end

with its crown of tentacles prove the relationship. Besides, examination of the interior reveals the presence of mesenteries arranged very much as in *Metridium*. One important structure of *Astrangia*, however, is never found in the sea anemone, and that is the carbonate of lime "skeleton." This structure at the base of the polyp is more definitely referred to under the name *corallite*, for it is not a true

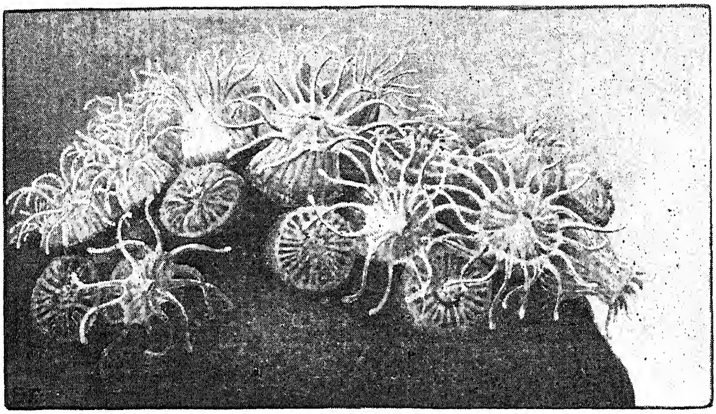


FIG. 147. Colony of coral polyps. (Enlarged)

skeleton. Several corallites are shown in the lower portion of the figure. The hard, radial plates repeat the number of pairs of mesenteries of the polyp, since each plate is formed between the members of pairs of mesenteries.

Definition of Anthozoa (Gr. *anthos*, "flower"; *zoa*, "animals"). The members of the class Anthozo'a are alike in having a soft, generally cylindrical body. The plan of structure is bilaterally symmetrical, as indicated in the arrangement of mesenteries in the gastrovascular cavity. Superficially, however, as indicated by the arrangement of the tentacles, there is radial symmetry. Into the single, partially divided gastrovascular cavity the mouth opens, and

through it food enters and unused particles are discharged. Nettling capsules, which are the organs of offense and defense, are at the surface of the tentacles and on the mesenterial filaments.

Coral Islands. Ever since Charles Darwin from 1831 to 1836 made his famous journey around the world in the *Beagle*, scientific explorers have engaged from time to time in the study of the life and structure of coral reefs and islands. We know from their researches that coral reefs are formed of great masses of carbonate of lime, largely as the result of the secretion of that substance by polyps.

Just as with other organisms, reef-forming polyps flourish wherever they become adapted to external conditions. The food they need is probably abundant anywhere in the seas, but they cannot endure the temperature common to regions outside the torrid zone. They can live in situations where the tide recedes from them for two or three hours, or in depths as great as fifty fathoms (300 feet), but the most general limit of depth for the greatest number of species is about twenty fathoms. A condition which checks their distribution near large bodies of land is the presence of silt, as in the fresh water that flows from the mouths of rivers. Fresh water itself when free from impurities is not especially detrimental to the growth of coral polyps. The most famous coral formations are found in the neighborhood of the Bahama Islands, in the Great Barrier Reef of Australia, in the Fiji Islands of the South Pacific Ocean, and in the Maldive Islands of the Indian Ocean.

When conditions permit, young coral polyps attach themselves to the sea bottom near a body of land, and by the process of secreting carbonate of lime, as described for *Astrangia*, extend upward toward the surface in the form of a long, narrow ridge skirting the land. When the ridge is so near the land that it leaves no channel, it is called a

fringing reef. If by subsequent changes, or as originally formed, a navigable channel lies between the ridge and the land, it is called a *barrier reef.* If the formation surrounds a body of water, which it nearly or completely cuts off from the sea, it is called an *atoll.* The most remarkable examples of atolls are the Maldive Islands.

Many theories have been advanced to account for the historical connection which is thought to exist between fringing reefs, barrier reefs, and atolls. Two of the more important of these theories will be discussed. Darwin believed that an atoll begins as a fringing reef surrounding an oceanic island, which may be of volcanic or other origin, and that as the island sinks from internal causes, the coral polyps build up carbonate of lime as long as they are within their range of favorable depth. The reef that at first was a fringing reef becomes a barrier reef, on account of the increase in distance between it and the decreasing area of sinking land. At last the top of the island disappears beneath the water, and the atoll remains. Professor J. D. Dana, and others, have published evidence in support of Darwin's *subsidence theory,* but the *erosion theory* suggested by Sir John Murray, leader of the exploring expedition of the *Challenger* (1850), has probably more adherents at the present day. The erosion theory has been modified and extended, chiefly by Dr. Alexander Agassiz. According to this theory coral polyps may form a fringing reef about an oceanic island. The reef continues to grow, while the soil or rock of the island is carried away by rains and by rivers. The solution of the soil and rock is caused by the temporary chemical union of these substances with carbon dioxide derived from dead animals and plants. The idea is that in the course of a few centuries an entire island could be worn away, and the atoll left with its lagoon of water partially connected with the sea.

Dr. Murray suggested also the probability of atolls being formed without the preliminary stages of fringing and barrier reefs. If coral polyps were to attach to a submerged plateau not too deep for them to live on, the small colony would grow upward and extend itself radially, something like the flaring sides of a shallow washbasin. As the mass grows larger the polyps at the center would be killed by the detritus collecting from the broken pieces of coral rock at the wave-beaten margin, and the rock already formed at the center would be worn and scooped out by erosion with coral sand.

Coral atolls are imperishable bulwarks against the sea, and in some cases have formed the beginning of strips of land sufficiently wide for wild races of men to live upon.

Definition of Cœlenterata (Gr. *koilos,* "hollow"; *enteron,* "intestine"). Arranged in the order of their increasing degree of specialization, the three classes that make up the phylum Cœlentera′ta are Hydrozoa, Scyphozoa, and Anthozoa. The classes constitute a fairly distinct phylum by including animals with radially symmetrical bodies (at least in external appearance) in which there is but one cavity. This cavity, joining the mouth opening, is the digestive cavity, and is not separated from a body cavity, as in higher animals (whence the derivation of the name of the phylum). The body has but two germ layers, — the ectoderm and the endoderm. In this particular it is different from every phylum of animals heretofore described. The characteristic organs of offense and defense are the nettling cells.

CHAPTER XXVI

THE BATH SPONGE AND SOME ALLIES: PORIFERA

> The unending shapes of plants, the rainbow's varied hues,
> All these the lowly sponge on ocean's bed renews.

Habitat and Form. Sponges live in the ocean both in shallow and in deep waters, and members of one family live in fresh water. Some kinds have no characteristic shape of their own, for they merely form crusts over rocks or other objects (Fig. 148). Some have a definite cup-like shape, while others grow as branching structures or are solid rounded masses. Sponges are animals of a very low type of organization. They have no organs of locomotion. In fact they have no highly specialized organs of any sort. As a consequence in general appearance they rather closely resemble plants.

Structure. One of the most characteristic features of a sponge is the practically solid body penetrated by numerous openings (Figs. 148, 149) which lead into an internal system of spaces or tubes. There are no true body cavities. The systems of openings and tubes penetrating the body are simply channels for the surrounding water to pass through (Fig. 149). In passing through the body, the water brings food to the tissues. The form of the body is largely due to supporting or skeletal material. In many of the sponges the skeleton is made up of *spicules* of lime or of a glass-like (silicious) material. Another type of framework, or skeleton, in sponges is a soft fibrous material arranged in the form of a network running all through the body. The sponges used in house-cleaning and usually sold under the

name "bath sponges" are but the skeletons of sponges of this last type. The tissues of the dead sponge are allowed to disintegrate and fall away leaving only the skeleton or framework of fibers as the part desired for market.

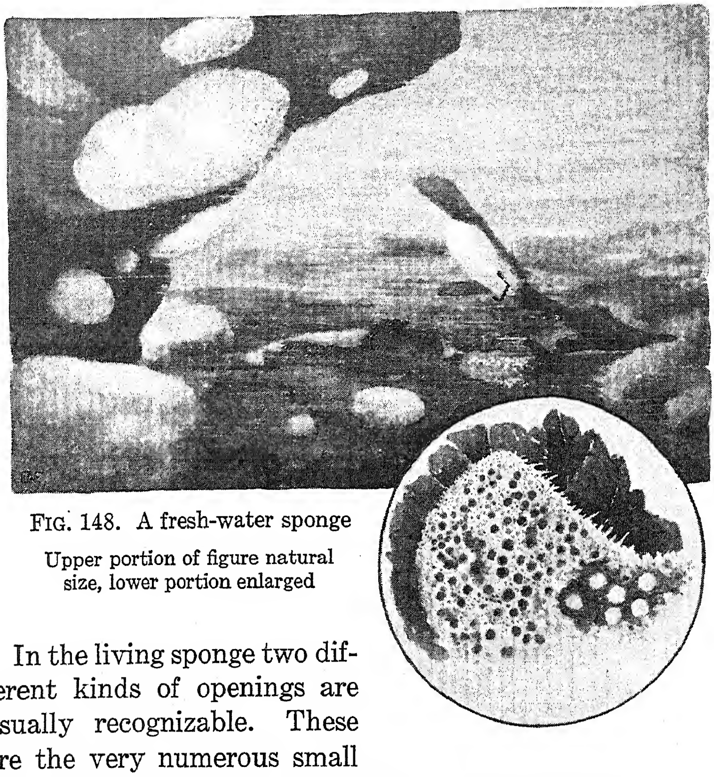


FIG. 148. A fresh-water sponge

Upper portion of figure natural size, lower portion enlarged

In the living sponge two different kinds of openings are usually recognizable. These are the very numerous small pores scattered over the surface of the body, and a few larger openings. Each of the larger openings is called an *osculum* (Lat., "little mouth"), because it was long thought that this opening was the mouth leading into a digestive canal. Examination of a living sponge shows that this is not true. Water bringing minute particles of food passes in through the small pores and leaves the body of the sponge by way

of the osculum. Many of the sponges are really colonies produced by budding around the base of a single individual.

Some of the spaces within a sponge are lined with specialized cells which were part of the endoderm during embryonic development. These endoderm cells are furnished with long thread-like appendages called *flagella*. When these flagella vibrate they force the water out through the osculum and thus draw in a fresh supply of water through the pores in the surface of the body. Food particles contained in the water are taken directly into the protoplasm of the endoderm cells. Digestion takes place inside the cells, not in a digestive cavity such as has been described for all other free-living animals treated before in this text.

Reproduction. Reference has already been made to the fact that budding occurs in the sponges. They also reproduce sexually. Eggs and sperms are produced in the mature sponge. Fertilization takes place inside the body of the parent. The egg develops into an ovoid larva covered with flagella. After leaving the body of the parent the larva swims about for a while, finally settling down on some solid object, where it transforms and grows into an adult sponge.

Fresh-Water Sponges. The sponge of Fig. 148 (*Heteromeye'nia ry'deri*) is found quite generally in ponds and quiet brooks, at least as far west as the Mississippi River. It grows on the under side of overhanging submerged rocks, and on dead sticks and leaves. The largest specimens are not usually more than one inch across. Each mass of sponge clings flat against the supporting substance, and seldom is more than one-eighth of an inch thick. The sponge yields slightly on being pressed with the finger. The surface looks rough, but to the touch it is smooth. The color is grayish; occasionally specimens are found with a part or all of the mass green. This is due to the presence of a green alga

growing in the sponge. Besides the species here described, there are numerous other species of sponges living in fresh water.

In addition to sexual reproduction, fresh-water sponges reproduce also by means of special organs called *gemmules,* which are about one fiftieth of an inch in diameter (Fig. 148). These structures are produced in the sponge mass during the summer. Their use is to carry the species over the unfavorable season after the destruction of the parent sponge, which usually takes place in the fall. The gemmules are really buds within the tissue of the sponge which become surrounded by a protective covering.

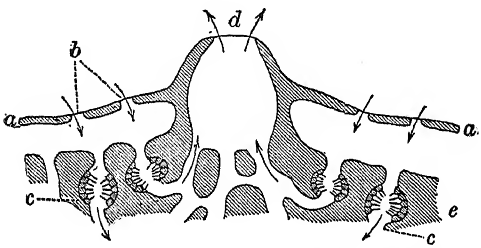


FIG. 149. Section of fresh-water sponge. (Much enlarged)

a, surface; *b,* dermal pores; *c,* ampullæ, lined with collar cells; *d,* osculum. (After Huxley)

Relation to Environment. Perhaps no group of animals has so wide a distribution in water as sponges. In fresh water, and in the sea from the very margin of low tide to the greatest depth of ocean yet explored, and in all zones, various species of sponges are found. They live in every conceivable situation, adapting themselves in form of mass to the particular place in which they grow. Branched species, like *Microci'ona prolif'era,* in the frontispiece, vary much in form and arrangement of branch. Incrusting species on rocks, as in the frontispiece, follow every turn of the supporting substance. One species of *Clio'na* grows on shells of mollusks, and through the agency of a secretion its protoplasm consumes the substance of the shell and grows to fill the space thus made. In regions where the ocean bottom

is muddy, sponges grow stalks that keep the mass away from the mud, which if stirred up would smother the colony.

Many marine sponges, being thick and massive, and of loose texture, like the sulphur sponges, are very convenient harbors of refuge for myriads of small animals, chiefly Crustacea and worms. Undoubtedly the odor of living sponges, described by one investigator as resembling garlic, drives away fishes and other ravenous animals of large size that might feed on the little guests, or even on the sponge itself.

Economic Importance of Sponges. Some idea of the value of sponges is gained from the fact that $715,000 worth of sponges were sold in the chief sponge market at Tarpon Springs, Florida, during the season of 1925. In some of the shallow waters of the warm oceans, sponges are picked up from the ocean floor with long-handled rakes and tongs. Most of the market sponges are now gathered by divers who can work in the deeper waters.

Definition of Porifera (Lat. *porus*, "pore"; *ferre*, "bear"). By most investigators the sponges are considered a distinct phylum, Porif′era, including but a few classes (see page 307). It is evident that the Porifera are lower in organization than the Cœlenterata, for members of the phylum do not show indications of muscle cells, of nerve cells, or of sense organs. Neither are there special organs of offense. Protection is afforded by the spicules and the characteristic odor.

CHAPTER XXVII

AMŒBA AND SOME ALLIES: PROTOZOA

Gradual, from these what numerous kinds descend,
Evading even the microscopic eye!
Full nature swarms with life, — one wondrous mass
Of animals, or atoms organized.

JAMES THOMSON, Summer

Protozoa. There are untold millions of animals which are so very small that most people are not aware of their existence, for they may be seen only with a microscope. The simplest and many of the smallest of these are called Protozoa. They exist under every conceivable condition that will support life, and some even have the power, though dried up completely and blown with the dust, of coming to active life again if they get into suitable surroundings. Stagnant pools teem with these minute forms. Even most drinking water is populated with them, though fortunately most of them are harmless. Some inhabit the soil, and many species live as parasites in the bodies of other animals. In spite of their microscopic size each of these organisms carries on the same functions of life that are characteristic of the higher animals. In the higher animals there are special organs for metabolism, for reproduction, for movements, and for the various other functions performed by living animals. In the Protozoa all the functions of life are carried on by the parts of the smallest unit of living matter — a single cell. This cell feeds, moves, and produces other individuals like itself just as effectively as does man with his complicated organization. Thus, in spite of its minute size, each cell is a complete individual.

The Amœba. The amœba (*Amœ'ba pro'teus,* Fig. 150) is common in stagnant water of all lands, but it is so minute that it is impossible to be sure of its presence in a given place until examination has been made with a compound microscope.

One of the best ways to find large specimens of the amœba is to remove carefully from the bottom of a well-stocked fresh-water aquarium a few dead leaves. A medicine-dropper full of material from the surface of one of the leaves may yield several specimens. A short time after a few drops of the water have been mounted on a glass slide the amœbas will exhibit their characteristic structure and activities. The usual diameter of an amœba is about .5 mm. ($\frac{1}{50}$ inch).

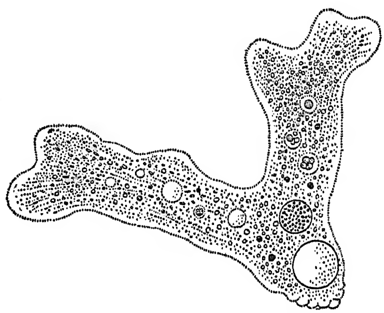


FIG. 150. Amœba. (Much enlarged)[1]

Structure and Appearance. The simplest structure encountered in any living animal is that found in an amœba. Under the microscope this minute animal is seen as a droplet of practically colorless jelly-like fluid only with difficulty distinguished from the water surrounding it. The granular protoplasm of which this body is composed is usually in motion, stretching out here and there as small lobes increasing in size until the whole body seems to flow along. The projections which produce this movement are called *pseudopodia* (false feet). The entire body is surrounded by a very thin nongranular layer called the *ectoplasm,* which contains within it a more fluid granular mass, the *endoplasm.* Part of the granular nature of the endoplasm is due

[1] From Sedgwick and Wilson's *General Biology.*

to the presence of food in all the stages of digestion and assimilation, and waste materials that are to be expelled from the body. There are two fairly conspicuous bodies within the endoplasm, the *nucleus*, which controls most of the acts of the cell, and the *contractile vacuole*, in which the liquid wastes are accumulated until the vacuole reaches its capacity. Then the vacuole bursts through the ectoplasm, throwing the liquid waste out of the body. In its functioning this contractile vacuole goes through regular cycles of gradual increase in size, followed by sudden disappearance.

In the life functions, oxygen dissolved in the surrounding water is absorbed directly by the protoplasm in the process of respiration. At the same time the carbon dioxide produced by the protoplasm is taken up by the surrounding water.

Microscopic plants and animals and parts of larger organisms serve the amœba as food. When a moving amœba approaches a food particle, pseudopodia extend on each side of the particle. As the animal flows along, the pseudopodia completely surround the object being taken as food, which becomes recognizable as a food vacuole within the endoplasm. Though a food vacuole lies in the protoplasm it is not part of the living amœba. The food must first undergo digestion under the influence of the surrounding protoplasm and become assimilated in a manner exactly similar to the processes that take place in the higher animals.

As an amœba continues to feed, it grows, but soon reaches a limit in size. It then undergoes reproduction. The nucleus divides into two equal parts, and the cytoplasm becomes separated into two masses. Each mass of cytoplasm surrounds a nucleus and becomes a new individual.

There are many species of *Amœba* and amœba-like forms, mostly living in stagnant water and having relatively little economic importance. In contrast with these some others

are highly important as parasites of man and other higher animals. In man one type of dysentery is produced by an amœba, and many diseased conditions are due to amœboid forms.

Euglena. A relative of *Amœba,* found in the same situations, is *Eugle'na vir'idis* (Fig. 151); it also is composed of one cell. *Euglena* has a more fixed arrangement of parts than *Amœba.* There is a blunt anterior end with a short, funnel-shaped mouth. Out of the mouth extends a long lash, or *flagellum,* which by its whip-like vibrations carries

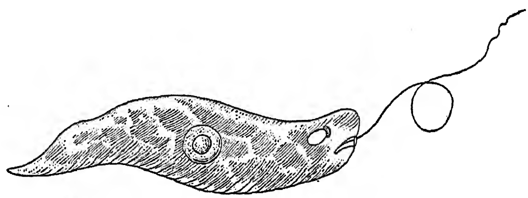


FIG. 151. *Euglena.* (Much enlarged)
After Saville Kent

the animal through the water. Behind the mouth is a small red eye-spot, which lies beside a clear space. This clear space has been found to be sensitive to light. The nucleus is near the middle of the body, and can be seen easily in the living animal, although the cytoplasm immediately about it is colored quite green with chlorophyll, — a coloring matter found in the green parts of plants.

Many biologists believe that *Euglena* is indeed a plant because, through the agency of its chlorophyll, it can use carbon dioxide as a raw food material, retaining the carbon and giving off oxygen when the organism is in the light. This creature illustrates the fact that it is impossible to classify all organisms as plants or animals.

As a rule *Euglena* moves with the lash forward, but the animal can turn in any direction, and can even change the shape

of its body considerably, but it does not form pseudopodia. Sometimes when being experimented on *Euglena* ceases moving, contracts into a ball, and encysts itself, just as it does in nature when it is surrounded by unfavorable conditions.

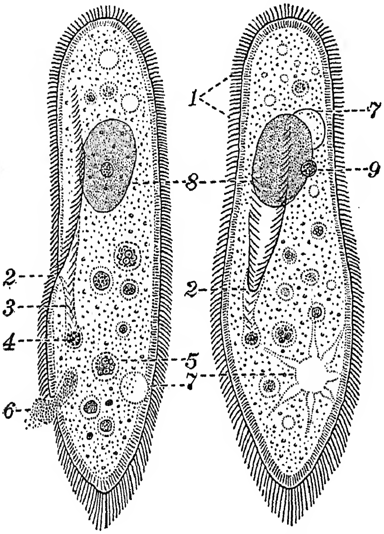


FIG. 152. *Paramecium*. (Much enlarged)

A, left side; *B*, ventral surface; *1*, cilia; *2*, mouth; *3*, gullet; *4*, food vacuole forming; *5*, food vacuole in cytoplasm; *6*, anus; *7*, contractile vacuole; *8*, macronucleus; *9*, micronucleus[1]

Paramecium. Perhaps no member of the phylum under discussion in this chapter has been observed by more students than has the slipper animalcule, *Parame'cium cauda'tum* (Fig. 152 *A*, *B*); and no member of its phylum has been so frequently made the basis of scientific discussions of cell structure and cell physiology. *Paramecium* lives in stagnant pools of fresh water in all lands. Specimens may be obtained in countless numbers by placing a quantity of hay in a jar of ordinary water and leaving it to stand for a few weeks. The bacteria developed in the decaying hay furnish a food supply favorable for rapid growth and reproduction of *Paramecium*.

There are several species of *Paramecium*, differing from each other slightly in form and in size. Most of these live in all sorts of standing fresh water but become most abundant if the water is stagnant.

[1]From Sedgwick and Wilson's *General Biology*.

As in *Amœba* and *Euglena,* the entire body of *Paramecium* is a single cell. The cell when moving freely has a definite shape, although it changes constantly in outline, owing to the fact that the irregularities in the body are whirled into view as the animal swims along in a slender spiral path.

Paramecium is about 0.2 mm. ($\frac{1}{125}$ in.) in length. The anterior end is rounded and the posterior end pointed. Right and left sides are, as indicated in the figures, determined by the position of the mouth (Fig. 152, *2*), which is on a surface called the *oral surface.* The entire surface of the ectoplasm is covered with great numbers of short, hair-like structures, called *cilia* (Fig. 152, *1*). The cilia are the organs of locomotion. They wave backward toward the posterior end, propelling the animal forward. A few cilia somewhat longer than the others lie in the groove that leads diagonally across the ventral surface to the mouth. Their function is to carry the food down the short gullet into the endoplasm.

The endoplasm, which, as already explained, is that portion of the cytoplasm lying between the nucleus and the outside layer of ectoplasm, is soft and semifluid. Food is passed into it by the *gullet* (Fig. 152, *3*), and immediately begins to float away from that point, surrounded by a little drop of water. These masses are called *food vacuoles* (Fig. 152, *4, 5*). While the current in the cell protoplasm is carrying the food vacuoles around, digestive fluid formed by the protoplasm is breaking up the food, liquefying it, and changing it chemically for the process of assimilation or building up into protoplasm. The indigestible particles are discharged from the cell by a small opening, the *anus* (Fig. 152, *6*). The waste derived from the food and protoplasm that is used up in the work of the animal is probably discharged in the form of liquid from two special organs, one near either end at the

dorsal surface. These are *contractile vacuoles* (Fig. 152, *7*). It is supposed that the liquid waste, when formed, flows through the protoplasm along somewhat definite channels to the point where it collects in a gradually increasing vacuole. Soon the maximum size is attained, and the vacuole bursts at the surface, the waste pouring into the water outside. The two contractile vacuoles alternate in contracting.

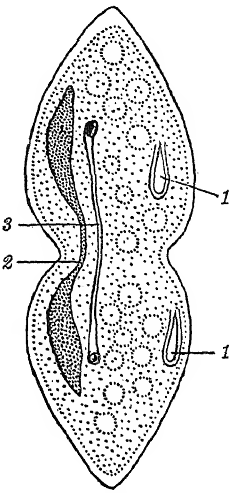


FIG. 153. *Paramecium* dividing. (Much enlarged)

1, mouth and gullet; *2*, macronucleus dividing; *3*, micronucleus dividing[1]

Paramecium has two nuclei; the large one is called the *macronucleus* (Fig. 152, *8*), and the small one the *micronucleus* (Fig. 152, *9*). The macronucleus is thought to be the seat of control of the general activities of the cell, while the micronucleus is the seat of control of the important process of reproduction.

Paramecium divides into two equivalent cells (Fig. 153), with half the macronucleus and half the micronucleus in each, probably because the volume of the cell becomes too great to be kept alive by the protoplasm of the relatively decreasing surface. As many as three or four generations of paramecia may be produced in a single day. The frequency of division of the cell depends upon the kind and abundance of food obtainable, upon temperature, and also upon a process known as *conjugation* (Fig. 154). This complicated process was worked out in great detail in 1888 by Maupas, a French librarian, who in his spare time studied the life history of *Paramecium* and other unicellular organisms.

[1] From Sedgwick and Wilson's *General Biology*.

In conjugation two paramecia unite temporarily in the manner indicated in the figure. A fraction of the micronucleus of each passes through the two contiguous layers of ectoplasm and unites with a similar fraction in the other animal. When this and certain other less essential phenomena have taken place, the individuals separate and continue the process of transverse division, but with greater frequency than before. Professor L. L. Woodruff of Yale University has found that conjugation is not necessary to the life of *Paramecium.* By isolating single specimens of *Paramecium* he kept watch so that each time the animal divided the parts were separated. In this manner conjugation was entirely avoided for ten years. During this time there were twelve thousand generations. Since the animals showed no ill effects we must conclude that *Paramecium* can continue to reproduce indefinitely without conjugation.

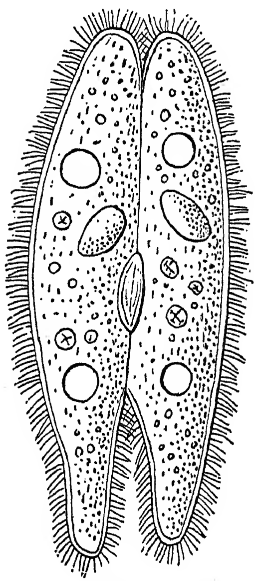


FIG. 154. Paramecia conjugating. (Much enlarged)

After Saville Kent

The Malarial Parasite. Many one-celled animals are parasitic. One of the most studied in recent years is one of the malarial parasites of man (*Plasmo'dium mala'riæ,* Fig. 155). There are several different species of malarial parasite. These differ one from another in appearance and in the nature of the diseases which they produce. While the most generally known species cause human malaria, other species live in birds and in other animals. The life history of these organisms is so long and complicated that we can give but a brief account of it here.

In its simplest form the animal resembles an extremely small amœba. In that stage it is found in the red corpuscles of human blood. There the parasite increases in size until it

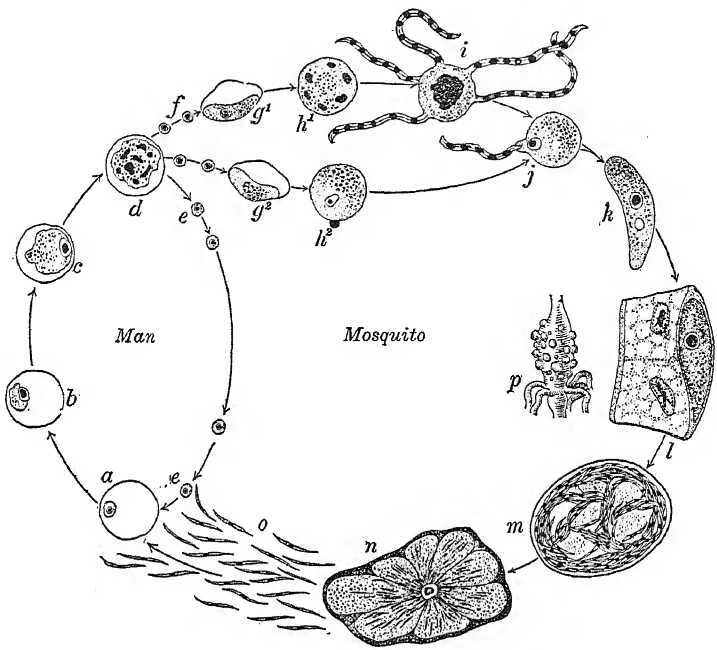


FIG. 155. Stages in the development of the parasite which causes malaria

Stages *a* to *e* occur in the human blood. The parasite lives in the red blood corpuscles (*a* to *d*). When blood from a malarial patient is taken into the body of a mosquito the spores develop into germ cells (*h* and *i*). After fertilization (*j*), the parasite enters the tissues of the mosquito (*l*) and multiplies rapidly (*m* and *n*), forming myriads of small spores (*o*) ready to infect other human beings when the mosquito bites them. *p* shows the stomach of a mosquito with swellings produced by the parasite. (After Gruenberg)

almost fills the corpuscle (Fig. 155, *c*); then it divides into small bodies called *spores* (Fig. 155, *d*). The process of spore formation causes the chill that accompanies malaria. When the spores burst from their spore cases (Fig. 155, *e*)

and from the blood corpuscles, a quantity of poisonous material is released and mingles with the liquid of the blood. This poisonous material induces the fever which always follows the chill. The released spores may enter red corpuscles again and, in forty-eight hours in one type of malaria and seventy-two hours in another, form spores once more.

Some of the *amœbulæ* (amœba-like stages) of the parasite have a different history. While most of them in the red corpuscles of a person go on reproducing nonsexually, as just described, some develop into a form which, by comparison with higher animals, we call the female cell (Fig. 155, h^2), and others into male cells (Fig. 155, *i*). If now the person be exposed to the bite of a mosquito of the genus *Anopheles*, the male and female cells of *Plasmodium* reach their full development in the human red blood corpuscles, as these rest in the stomach of the mosquito. Leaving the corpuscles, the two cells unite to form a worm-like cell (Fig. 155, *k*), which penetrates to the outer wall of the stomach of the mosquito, where it increases in size to form a large sphere (Fig. 155, *p*). In a short time the sphere subdivides into countless extremely minute *blasts* (Fig. 155, *m*). These make their way through the body cavity of the mosquito to the salivary glands (Fig. 155, *n*). Penetrating to the interior of those glands, the blasts enter the ducts, and are carried outward and down the insect's proboscis by the saliva when the mosquito bites another person. Then in the human blood the blasts enter the red corpuscles and become amœbulæ, thus completing a cycle.

Prominent among the scientific men who since 1896 have discovered the facts of the life history of the malarial parasite are Dr. Ross, of India, and Professor Grassi, of Italy. Upon their discoveries, and those of others, are based the numerous operations against the mosquito in the vicinity of large cities.

Definition of Protozoa (Gr. *protos,* "first"; *zoa,* "animals"). The four members of the phylum described in this chapter were selected as representatives of the four classes that make up the phylum: *Amœba proteus,* of the class Sarcodi′na; *Euglena viridis,* class Mastigoph′ora; *Paramecium caudatum,* class Cilia′ta; and *Plasmodium malariæ,* class Sporozo′a.

Although in each class the genera differ widely, all the members of the four classes agree in being composed of single cells. Nearly all species are microscopic in size.

Reproduction is brought about by division of the cell, and in some cases by specialized germ cells, as in the higher animals.

In all the Protozoa discussed in this text, the body consists of a single cell. However, in many species the cells, after division, remain united in clusters. These groups, in some instances, are only temporary and finally break apart into entirely independent individuals. In other species, the cells remain united permanently. Such groups, whether permanent or temporary, are called *colonies.* Division of labor or specialization occurs in many of these colonies, for only certain of the cells are capable of reproduction while the other cells care for the nutrition and locomotion of the colony.

CHAPTER XXVIII

THE PAST HISTORY OF INVERTEBRATES AND THE BEGINNINGS OF THE VERTEBRATES

I wrote the past in characters
Of rock and fire the scroll,
The building in the coral sea,
The planting of the coal.
EMERSON, Song of Nature

Vertebrates and Invertebrates. However various in form and structure the members of the phyla thus far discussed are, they have in common at least this negative character, that in none of them has a backbone been developed. For this reason they are collectively termed *Invertebrates* (Lat. *in*, "not"; *vertebratus*, "vertebrate"); the animals which have a backbone are called *Vertebrates*. It will be worth our while, before beginning the study of the vertebrates, to consider some general questions of interest in connection with the evolution of the invertebrate phyla, and then to describe briefly some peculiar forms which appear to stand between the invertebrates and the vertebrates.

THE INVERTEBRATES OF PAST AGES

Sources of Information. There are three sources of information which the zoologist may draw upon in his endeavor to discover the relationship which the animals of the past and the present bear to each other throughout the long series from the lowest to the highest. These sources of information are the geological record of species, comparative anatomy or morphology, and the stages in the development of the individual. We shall consider first the record of

geology, and in order to do this intelligently we shall have to begin far back, for perhaps more than any other science geology requires of the mind of man vast sweeps of the imagination to form even faint conceptions of the illimitable processes that have brought the earth to its present state. Scarcely less awe-inspiring is the contemplation of the changes that must have taken place in living things since life began in the ocean and on the land. Great as the time and changes were before the earth had life upon it, greater still may be the time that the processes of evolution have required to develop all the forms of life in their complexity.

Archæan Time. The earliest period of the earth's geological history is termed the *Archæan Era* (Gr. *archaios*, "ancient"). At first all the substances, including the water which now covers three quarters of the earth's surface, were held suspended in the atmosphere, owing to the high temperature. Later there came a time when the waters condensed, and the surface, cooled still further, permitted the water to cover the rocks of the early crust entirely or in part. Stupendous volcanic upheavals must have been frequent as fire and water struggled for the mastery. During this time, of course, no life was possible. As the crust continued to cool it was upheaved and formed land. When the waters had cooled sufficiently to permit of it, life appeared, but in what form we do not know. It is thought that this early life must have been plant rather than animal in its nature. Plants are able, with the exception of the fungi (mushrooms, bacteria, and the like), through their green substance, called chlorophyll, to manufacture their food materials out of simple chemical substances. All animals lack this power and consequently depend upon green plants to manufacture their food for them. Flesh-eating animals get their food indirectly from plants, for the food manufactured by plants is eaten by plant-eating animals, and these in turn become

the prey of the flesh-eaters. It stands to reason that the first living things must have been able to provide for themselves and therefore must have been plants. As regards the temperature at which life became possible, it is known that plants live now in the hot springs of the West in water reaching 180° F.

There is very little direct evidence to indicate the character of the life in the Archæan Era, but in all probability it was of the simplest structure, even simpler than the single-cell organisms of today. Although fossil remains of that time are wanting, beds of limestone and graphite which were formed then, point to the existence of life, for similar beds formed in later eras are known to have been made through the agency of organisms (polyps, mollusks, and the like, and plants).

The Age of Invertebrates. Following the Archæan Era, several succeeding geological periods may be, for our purpose, grouped under the general term, *Age of Invertebrates*, from the predominance of these forms of life. The era was very long, undoubtedly to be reckoned in millions of years. We have no knowledge of the exact time that the different species appeared, nor of the exact length of time each existed. Neither do we know from actual specimens all the stages of evolution through which the early forms of life may have passed in coming to the form and structure in which we know their kin today. The intermediate types have been lost on account of one catastrophe or another in the history of the world.

In the beginning of the era, life was marine, as far as fossil records indicate. The earliest fossils are of sponges, corals, sea lilies, worms, mollusks, and trilobites. Subsequently land animals made their appearance in forms like the arachnids and the insects. Before the close of the era a class of vertebrate animals, the fishes, had come into existence.

Evidence from Embryology and Morphology. Frequently the only way the zoologist may know of the kinship of certain groups is by studying their early stages of development. Since all the animals composed of more than one cell reproduce at one time or another by means of eggs and sperms, we see that all animals, however great the differences between the adults may be, are alike in being composed of one cell at the beginning of development. Furthermore, the degree to which the young of two different groups of animals resemble each other in the details of their development is believed to be a measure of the relationship existing between the groups. This theory is based upon the very generally accepted belief that each individual in the course of its development repeats in an extremely short time the history of its race. The *Recapitulation Theory* is the name by which this generalization is commonly known.

All those animals which have few organs show relatively few changes in development, in comparison with those animals which have numerous complicated organs. A hydra, for example, is a very simple form compared with an earthworm. Not only has a hydra fewer organs than an earthworm, but reference to the latter's development will show that the two layers of cells which constitute an entire hydra represent a very early stage in the development of an earthworm.

The third germ layer, the mesoderm, offers a beginning place for organs not developed in the ectoderm and endoderm, and groups of animals possessing it develop more kinds of organs than those which do not have it; that is to say, they show greater differentiation. All animals except the Protozoa and the cœlenterates have a mesoderm.

If we were to begin at once to arrange all animals in a regular graded series, on the basis of what we learn from morphology and from embryology, we should have a diffi-

cult task. The number of facts that it is necessary to know is so considerable that even today systematic zoologists are not agreed on important details of grouping animals in a complete system of classification. Besides, the doctrine of evolution takes into account the fact that the phyla of animals have not developed in a direct line, but as branches from a previously existing stem. The whole system of animals might be represented by a stem and a series of branches resembling a tree; but whereas in a tree we can trace down one branch and out any other, in the diagram suggested some of the branches would not be connected with the stem at all, because the organisms which would stand in the connecting places have disappeared both in living and in fossil form.

However, we can see very clearly that the Protozoa, being composed of a single cell, are the lowest of all animals; and that the Porifera, with their structure showing no sign of digestive organs, muscle cells, nerve cells, or sense organs, are the simplest of the many-celled animals (*Metazoa*).

After considering all facts of structure and development, we may arrange the phyla in a series going from the simpler animals to the more complex (see page 307). But in doing this we must keep in mind that in some instances one group may be simpler than another in regard to certain organs or structures but more complex in other respects. It then becomes necessary to decide which of the differences is the most important. Furthermore, it is not unusual to find that some simple animals are really degenerate examples of a group that is relatively complex.

Invertebrates which resemble the Vertebrates. All the animals which have been discussed in the preceding chapters lack a backbone. The name "invertebrate" is therefore applied to them in contrast with the highest animals, or "vertebrates." For a long time a few animals which

lack a backbone have been admitted to resemble the vertebrates in other important respects. These peculiar forms show so many points of agreement with the vertebrates that zoologists now uniformly agree that they should be united with them in a larger group to which the name "chordate" is applied. This name is taken from the fact that a soft, rod-like structure called the *notochord* occurs in the position which is occupied by the backbone of a vertebrate. There are three of these groups of low chordates (Figs. 156, 157, 158) represented by the fish-like lancelet, the sac-shaped tunicate, and the worm-like *Balanoglos'sus.*

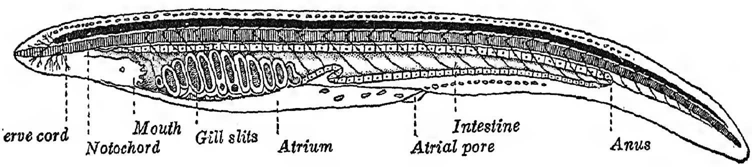


FIG. 156. The lancelet. (×2)
Modified from Kowalevsky

The Lancelet. The lancelet (*Amphiox'us lanceola'tus,* Fig. 156) is a fish-like animal about two inches long. It lives almost embedded in the sand at the sea bottom in Chesapeake Bay and in other warm ocean waters.

The *mouth* of the lancelet opens into a long *pharynx,* which has many pairs of *gill slits.* When water and food pass in at the mouth, the water passes through the gill slits, giving up oxygen to the blood in the gills, and then passes into a chamber partially surrounding the pharynx, called the *atrium,* and to the outside by the *atrial pore;* the food goes down the *intestine.*

Immediately above the intestine is the structure which corresponds in position to the backbone of higher animals; it is called the *notochord.* The notochord is soft throughout life, but it is sufficiently strong to act as a supporting rod

for the body. Parallel with the notochord and above it is the *spinal cord*, lying near the dorsal wall. The characteristics of structure which permit zoologists to consider *Amphioxus* a chordate are the presence of gill slits, a notochord above the intestine, and a spinal cord dorsal to the notochord.

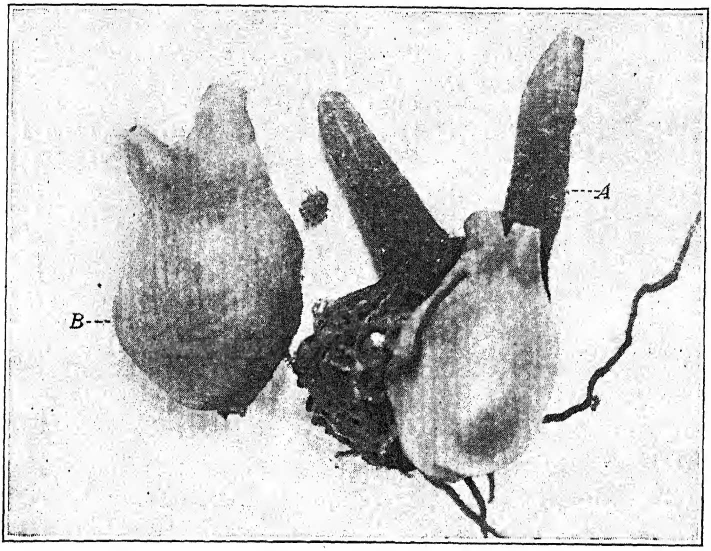


FIG. 157. Photograph of living sea squirts. (Natural size)
A, Styela; B, Cynthia

The Sea Squirt. As far as outward appearance indicates the sea squirts, *Sty'ela* and *Cyn'thia* (Fig. 157, *A*, *B*), seem to have nothing in common with vertebrates. Sea squirts live attached to rocks and wharves, and once attached never leave the place. The body is covered with a tough coat, or tunic, which gives the class its name, Tunica'ta. The food and oxygen are drawn through the opening in the upper tube, and the excess water and wastes are discharged by the lower tube. There is a pharynx with gill

openings, and a nervous system, but there is no indication of a notochord in the adult animal.

The adult tunicate is simpler in structure than the larva. The larva has very much the form of a frog tadpole, and it swims about. Its locomotor organ is a fin-like tail. In the larva there are structures which indicate vertebrate relationship. Extending through the middle of the tail is a *notochord* which is evidently a supporting organ. Dorsal to the notochord is the *nerve cord*. Below the notochord is the *alimentary canal*, and close by are the beginnings of the *gills*, with openings which, however, are not gill slits. When the larva reaches a certain stage of development, it fastens itself by *adhesive papillæ* to some fixed object. Then begins the process of degeneration of all distinctly chordate structures; the tail is absorbed, the notochord also disappears, and the nerve cord changes form. If it were not for what is known of the larva, the vertebrate relationship of tunicates would never be suspected.

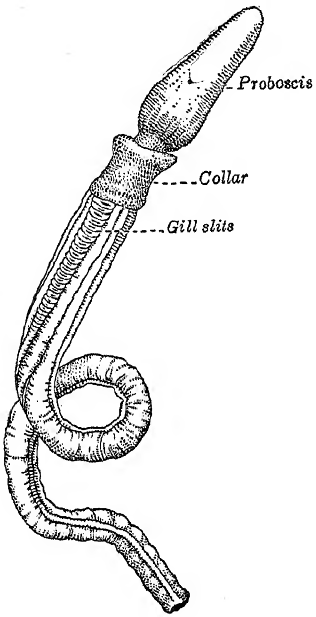


FIG. 158. Acorn-tongue worm. (Enlarged)

Modified from A. Agassiz

The Acorn-Tongue Worm. The acorn-tongue worm, *Balanoglos'sus* (Fig. 158) is found in the sand of seashores. It has a *proboscis* with a collar-like band at the base, both organs together somewhat resembling an acorn in its cup.

The *mouth*, at the base of the proboscis, opens into a *pharynx*, from which many pairs of *gill slits* open to the

exterior. There is a *dorsal nerve cord* and a *ventral nerve cord.* A notochord-like structure extends into the middle of the proboscis.

A Synopsis of the Animal Kingdom

The relative positions of the phyla are shown in the accompanying table. As regards the brief diagnosis of characters listed for each class it is of course assumed that, in addition, the statements made for the phylum apply to all the members of each class within that phylum. Attention should be called to the fact that in this table many of the less important or less well-known classes have been omitted. This applies especially to the Arthropoda and to the various phyla of worm-like forms.

The lowest chordates are sometimes called the Prochordates. In the following table the phylum Chordata is included. This makes it possible for us to have a complete list of the phyla contained in the entire animal kingdom, even though the higher chordates are not treated until later in the book.

PHYLA AND CLASSES OF THE ANIMAL KINGDOM

Phylum I. *Protozoa:* chiefly single-celled animals.
- Class 1. *Sarcodina:* move by pseudopodia. Ex. *Amœba proteus.*
- Class 2. *Mastigophora:* move by flagella. Ex. *Euglena viridis.*
- Class 3. *Ciliata:* move by cilia. Ex. *Paramecium caudatum.*
- Class 4. *Sporozoa:* reproduce by spores, entirely parasitic. Ex. *Plasmodium malariæ.*

Phylum II. *Porifera* (sponges): body with numerous pores, no organs.
- Class 1. *Calcarea:* with limy spicules. Ex. *Grantia.*
- Class 2. *Hexactinellida:* with silicious spicules. Ex. *Euplectella.*
- Class 3. *Demospongia:* with fibrous skeleton and frequently with silicious spicules. Ex. *Heteromeyenia ryderi.*

PHYLUM III. *Cœlenterata:* radially symmetrical, two cell layers, tentacles with stinging cells, with a single cavity serving as both digestive cavity and body cavity.

Class 1. *Hydrozoa:* usually two forms—polyp and medusa, the former with no folds in endoderm. Ex. *Hydra viridissima.*

Class 2. *Scyphozoa:* usually polyp and medusa, of which latter is larger, former with four folds in endoderm. Ex. *Aurelia flavidula.*

Class 3. *Anthozoa:* polyp only, endoderm with many folds. Ex. *Metridium marginatum.*

PHYLUM IV. *Ctenophora:* similar to medusa with eight bands of cilia for locomotion, but a single pair of tentacles. Ex. *Pleurobrachia pileus* (sea comb).

PHYLUM V. *Plathelminthes* (flatworms): body flat, bilaterally symmetrical, no body cavity.

Class 1. *Turbellaria:* free-living, body covered with cilia. Ex. *Procotyla fluviatilis.*

Class 2. *Trematoda* (flukes): always parasitic, digestive tract present. Ex. *Fasciola hepatica.*

Class 3. *Cestoda* (tapeworms): always parasitic, no digestive organs. Ex. *Tænia saginata.*

PHYLUM VI. *Nemathelminthes* (roundworms): round, not segmented, with a digestive system and a body cavity.

Class 1. *Nematoda:* characters as for phylum. Ex. *Ascaris lumbricoides.*

PHYLUM VII. *Trochelminthes* (wheel animalcules): many-celled, minute, with wheel of cilia about mouth.

Class 1. *Rotifera:* characters as for phylum. Ex. *Hydatina.*

PHYLUM VIII. *Annelida* (jointed worms): body segmented, with distinct body cavities.

Class 1. *Chætopoda:* bristles for appendages. Ex. *Lumbricus terrestris.*

Class 2. *Hirudinea* (leeches): no bristles. Ex. *Placobdella rugosa.*

PHYLUM IX. *Molluscoidea:* with a crown of ciliated tentacles on anterior end of body.

Class 1. *Bryozoa* (moss animals): usually colonial, digestive system complete. Ex. *Plumatella.*

PHYLUM X. *Echinoderma:* radially symmetrical, with body cavity, locomotion usually by tube feet, limy plates in skin.

Class 1. *Asteroidea* (starfishes): a central disk with five or more arms, body cavity extending into arms. Ex. *Asterias vulgaris.*

Class 2. *Ophiuroidea* (serpent stars): a disk and five slender or branched arms, no body cavity in arms. Ex. *Gorgonocephalus.*

Class 3. *Echinoidea* (sea urchins): hemispherical, or flat disk without arms. Ex. *Strongylocentrotus drobachiensis.*

Class 4. *Holothuroidea* (sea cucumbers): long soft body with feathery tentacles about mouth. Ex. *Cucumaria chronhjelmi.*

Class 5. *Crinoidea* (sea lilies): a cup with movable arms, attached by a stalk. Ex. *Pentacrinus blakei.*

PHYLUM XI. *Mollusca:* not segmented, usually covered with a shell.

Class 1. *Acephala* (clams): no head, shell usually in two parts. Ex. *Mya arenaria.*

Class 2. *Gasteropoda* (snails): head with tentacles, a single shell, usually coiled. Ex. *Physa.*

Class 3. *Cephalopoda:* with a circle of arms about the mouth, shell usually internal, free-swimming. Ex. *Ommastrephes illecebrosus* (squid).

PHYLUM XII. *Arthropoda:* body with an exoskeleton, segmented, with body cavity, and with paired jointed appendages.

Class 1. *Crustacea:* skeleton limy, two pairs of antennae. Ex. *Cambarus limosus.*

Class 2. *Arachnida* (spiders and ticks): no antennae, usually four pairs of legs. Ex. *Miranda aurantia.*

Class 3. *Diplopoda* (thousand legs): land-living, most of segments with two pairs of legs each. Ex. *Spirobolus.*

Class 4. *Chilopoda* (centipeds): one pair of legs to each of many somites, body flattened. Ex. *Scutigera forceps.*

Class 5. *Hexapoda* (insects): one pair of antennæ, three pairs of legs, tracheæ for respiration. Ex. *Melanoplus femur-rubrum.*

PHYLUM XIII. *Chordata:* with backbone or a rod called the notochord in its place, gill slits in either adult or embryo, nerve cord dorsal to digestive tract.

A. The Prochordates: never having any backbone. Ex. *Amphioxus lanceolatus.*

B. Vertebrates, with a bony or cartilaginous backbone.

Class 1. *Pisces* (fishes): breathe by gills, body usually covered with scales. Ex. *Perca flavescens.*

B. Vertebrates (Continued)

Class 2. *Amphibia:* breathe by gills or lungs, skin. moist, usually two pairs of legs. Ex. *Rana clamitans.*

Class 3. *Reptilia:* breathe by lungs, body covered with dry scales, heart with three chambers. Ex. *Sceloporus undulatus.*

Class 4. *Aves:* breathe by lungs, body covered with feathers, heart with four chambers. Ex. *Columba livia.*

Class 5. *Mammalia:* breathe by lungs, body covered with hair, heart with four chambers, suckle young. Ex. *Sciurus carolinensis.*

CHAPTER XXIX

THE YELLOW PERCH

Give me some observations and directions concerning the *Pearch* for they say he is both a very good and a bold biting fish, and I would fain learne to fish for him.

IZAAK WALTON, The Compleat Angler

Habitat and Distribution. Brilliant in coloration, abundant and easy of capture, and possessing a firm, white flesh of delicate flavor, it is no wonder that the yellow perch (*Per'ca flaves'cens*, Fig. 159) is one of the best known of the fresh-water fishes of the United States. Though found in streams, especially in those with quiet reaches of water, the yellow perch is more truly a creature of ponds and lakes. There it prefers a pebbly or sandy bottom. Its range extends from Labrador to Georgia in the fresh-water rivers and the lakes along the Atlantic coast, and westward in the region of the Great Lakes and upper Mississippi Valley. Though originally absent from the Far West, it has been introduced with success into the lakes of Washington, Oregon, and California. In structure and habits our yellow perch very closely resembles the perch of Europe, referred to in the quotation at the head of this chapter, and by some authors it is considered to be identical with the latter species.

External Structure. The body of the perch is elongate, slightly compressed from side to side, and tapers toward both ends. Three divisions are apparent, the *head*, *trunk*, and *tail*; several appendages, the *fins*, are attached to the body. The covering is a smooth *skin*, containing pigment cells, to which the colors are due, and glands which secrete mucus. Within pouches in this skin are transparent *scales*,

which overlap, like the shingles on the roof of a house, and form a coat of mail, incasing the fish from head to tail. Along a clearly defined *lateral line* the scales are somewhat modified, and beneath them are sense organs the functions of which have been variously stated. These organs are sensitive to mechanical jars of a low rate of frequency, thus standing between organs of touch proper and those of hearing.

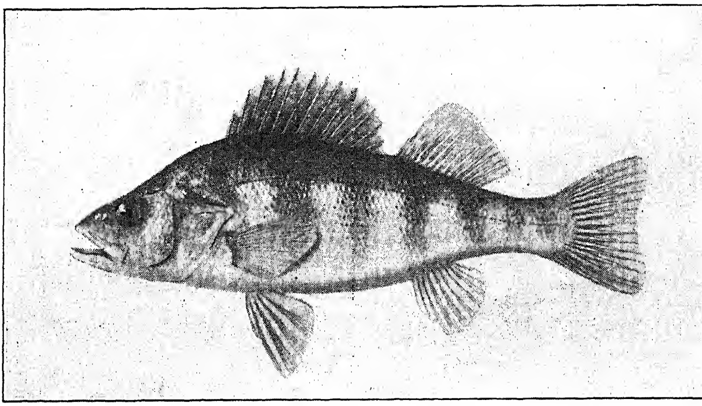


FIG. 159. Yellow perch[1]

At the anterior end of the head are the *jaws*, armed with teeth for seizing food. The *eyes* have no eyelids. Just in front of the eyes are the *nostrils*, two on either side. They have no communication with the mouth. Behind the eyes, on each side of the body, is a movable flap called the *operculum*, beneath which are the red comb-like *gills*.

There are five fins, three unpaired and two in pairs. Of the unpaired fins those on the back are called the *dorsal* fins, the one on the under side the *anal* fin, and the one at the tail the *caudal* fin. The more anterior of the paired fins are the *pectoral* fins; the more posterior and lower, the *ventral*, or

[1]From *The Fishes of Illinois*, by S. A. Forbes and R. E. Richardson.

pelvic, fins. The fins are supported by *fin rays* of two sorts, the one hard, unsegmented, and unbranched (Fig. 160); the other soft, segmented, and branched.

The Digestive System. The *mouth* is large. *Teeth* are borne not only on the jaws but also on the roof of the mouth (Fig. 160). On the ventral surface of the mouth is a rather large, fleshy *tongue.* Behind the tongue is the *pharynx,* with gill slits on both sides, which allow water from the mouth to pass into the gill chamber. From the pharynx a short *esophagus* leads to the *stomach.* Several *pyloric cæca* open into the *intestine,* increasing its absorbing and secreting surface. The intestine ends ventrally at the *anal opening* anterior to the anal fin. The liver-secretion, called bile, is stored in a *gall bladder* attached to the posterior surface of the *liver,* and finds its way into the alimentary canal through the *bile duct.* Close to the alimentary canal, but not opening into it, is a bright-red organ called the *spleen,* the function of which is not positively known.

The Circulatory System. The *heart* is placed in a large *pericardial cavity,* the posterior wall of which forms a thin membrane separating the heart from the other organs of the body cavity. Two divisions of the heart may be clearly distinguished, an *auricle* and a *ventricle* (Fig. 160). The blood, driven from the heart by the contraction of the ventricle, is forced through an *artery* (the *aorta*) with a bulbous base (*bulbus aortæ*) to the gills, where it gives off its carbon dioxide and takes on oxygen. After leaving the gills the blood is collected into a dorsal artery, which carries it through the body, giving off branches to the various organs. In the *capillaries* of the different organs it gives up its oxygen, collects waste products, and makes its way through the *veins* to the auricle, whence it enters the ventricle to repeat its circulation. Valves in the heart and in the course of the venous circulation prevent the backward

flow of the blood. In addition to the blood, a white fluid (lymph) circulates through the body in vessels called *lymphatics*. The function of the lymph is supplementary to that of the blood.

The Respiratory System. The principal organs of respiration are the *gills*, eight in number, four on either side. Each gill consists of a bony *arch*, on the anterior surface of which are teeth-like *gill-rakers*; on the posterior surface are the delicate *gill filaments*. In this position the filaments are constantly bathed by a current of water, which passes from the mouth cavity out beneath the operculum. In the dorsal part of the body cavity is a large *air bladder* (Fig. 160). In the lining of the wall of the air bladder is a network of blood vessels, grouped into gland-like "red bodies." By the absorption and formation of gas by these blood vessels the weight of the fish can be maintained nearly equal to that of the water it displaces. The air bladder is probably useful also as a reservoir of air, for it has been found that in a perch suffocated in stagnant water the oxygen in the air bladder, which normally amounts to about one fifth of the volume of the inclosed gas, had been entirely absorbed and replaced by carbon dioxide and nitrogen. In some fishes the air bladder communicates with the alimentary canal by means of a tube called the *pneumatic duct*. In the perch this duct is present in early life, but it soon closes, remaining, however, as a fibrous cord.

The perch, like other fishes, is usually spoken of as cold-blooded, since its body temperature is little above that of the surrounding medium. Compared with the higher vertebrates, — the birds, for example, — very little oxygen is required for respiration, and the circulation is comparatively slow.

The Excretory System. The principal organs of excretion are the *kidneys*, placed just above the air bladder and below

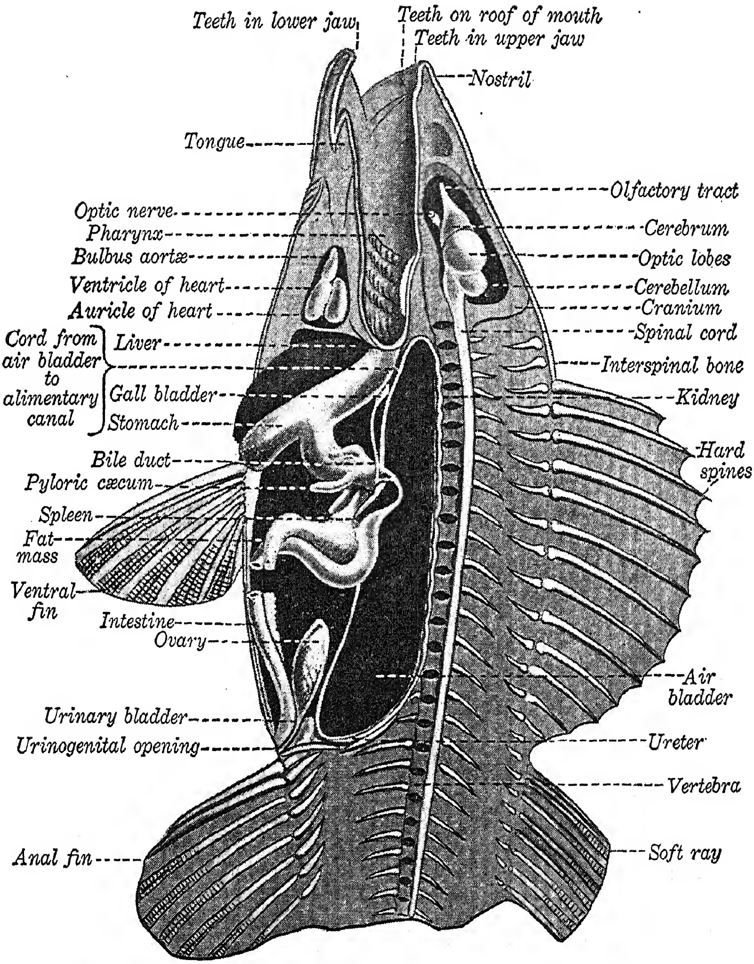


FIG. 160. Dissection of the yellow perch. (Reduced)

the backbone. From the kidneys two tubes, the *ureters*, lead, after union, to the *urinary bladder*. The contents of the urinary bladder are carried to the surface of the body at the *urinogenital opening*, just posterior to the anal opening.

The Skeletal System. So far in our study of the animal kingdom the skeletal, or protecting and supporting, parts have been found chiefly on the outside; in the fish there is a well-developed internal skeleton formed of bones composed largely of phosphate of lime. Running from head to tail through the body is the backbone, or *vertebral column*, consisting of a number of separate bones called *vertebræ* (Fig. 160) and continued into a brain case, or *cranium*, at the anterior end. Bones also form the foundation of the upper and lower jaws, and support the gills and tongue. Attached to the backbone are a number of *ribs*, which inclose and protect the organs of the body cavity. A row of small bones (*interspinals*) supports the unpaired fins. The pectoral and ventral fins are each supported by a framework of bones forming respectively a *shoulder girdle* and a *hip* or *pelvic girdle*.

The Nervous System. Four divisions are quite clearly marked in the *brain*, — the *cerebrum* (Fig. 160); the two large rounded *optic lobes*; the medially and dorsally placed *cerebellum*; and the *medulla oblongata*, the latter tapering posteriorly into the *spinal cord* (see Fig. 160, where the medulla is shown though not labeled). Anteriorly the brain is prolonged into the *olfactory tracts*, which communicate with the nostrils; *nerves* extend to the different sense organs and to the various parts of the body.

The *ears* of the perch consist of two closed cavities on opposite sides of the cranium, containing concretions of carbonate of lime, called *otoliths*, or ear stones. No one knows exactly to what extent fishes hear. Some, at least, are

capable of appreciating sound vibrations. The ears also serve as organs of equilibration, by aid of which the fish is able to maintain its balance. The sense of touch is located in the skin generally, and in the lateral-line organs. The sense of taste is not greatly developed in the perch, and the eyes are not adapted for vision at any great distance. The organ of smell of fishes is peculiar among vertebrates in that it has no connection with the respiratory system.

The Muscular System. The muscular system consists principally of a long, thick *muscle* on either side, stretching from head to tail. In the young fish this muscle is divided into segments extending vertically and corresponding in number with the vertebræ. As the young fish begins active existence the muscle segments are bent and twisted, so that for a portion of their extent they seem to run zigzag.

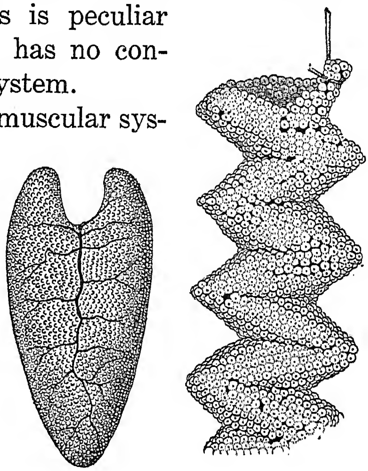


FIG. 161. Eggs of perch before and after laying. (Reduced)

From *Bulletin United States Fish Commission*

The Reproductive System. Both the *ovary* of the female (Fig. 160) and the *spermaries* of the male are of large size in the mature perch. They open to the surface at the urinogenital opening.

Development. Early in the spring the adult perch, which have spent the winter in the deepest waters of ponds or lakes, often without feeding very much, draw toward the shore. The colors, especially on the males, begin to brighten, till an adult perch in the full glory of his breeding colors is one of the most beautiful objects in his domain. The time of spawning varies with the climate: in the South it begins

as early as March; in New England, in May. The eggs are laid in shallow water in a ribbon-like mass (Fig. 161), which, after absorption of water, is sometimes six or seven feet long and two inches in diameter. This great mass, which contains thousands of eggs (over a hundred thousand have been counted in a two-pound perch), is fertilized by the male emitting his sperm (milt) over it. The eggs form a large part of the food of other fishes and aquatic birds. In from two to four weeks, depending on the temperature, the young perch hatches from the egg, at first with the yolk sac attached to the ventral surface (compare Fig. 162). After absorption of the yolk sac, which soon occurs, the young perch differs from the adult chiefly in its smaller size and lighter color, and in the relatively greater size of head and eyes as compared with the rest of the body.

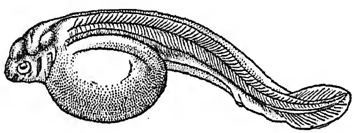


FIG. 162. Young sturgeon with yolk sac. (Enlarged)

After Ryder

Relation to Environment. The whole organization of the perch marks it at once as one of the predatory type of animals, — those which hunt their food and depend upon their superior strength or agility to obtain it. As Izaak Walton long ago said of its European relative, the yellow perch is "one of the fishes of prey that, like the *Pike* and *Trout*, carries his teeth in his mouth, not in his throat, and dare venture to kill and devour another fish." The shape of the body is precisely that which offers least resistance to motion in the water. The strong lateral muscles give great power to the caudal fin, which, by a slight lateral motion, drives the fish forcibly forward. Lateral and median fins assist in maintaining equilibrium, in steering, and in raising and lowering the fish in the water.

The colors of most fishes are protective in their nature, and the perch is no exception to this general rule. From above, the olivaceous back is with difficulty distinguished from the water itself or the bottom below; from beneath, the white under parts are colored like the surface of the water or the atmosphere above. The mottled sides also serve to render the perch less conspicuous in lights and shadows among weeds and rocks on the bottom. It has been noted that in some instances where perch live both in a large lake and in its tributaries, as in Lake Michigan and the rivers which flow into it, the lake fish have a tendency to lighter general coloration and to disappearance of the dark vertical bands. It has been suggested that this difference in color is due, in part at least, to the smaller amount of light in the lake, combined with the absence of dark lurking-places.

Sight is probably the best-developed sense, though, as already stated, the eyes are not adapted to vision at a great distance. To test the power of sight discrimination, an observer dropped into an aquarium pieces of wireworms (larvæ of click beetles) alternately with similar bits of earthworms. Nearly every time one or more of the bits of wireworm were seized by the perch, only to be dropped a moment later. The fishes did not seem to make any permanent association between the appearance of the wireworm and its inedible character.

Perhaps the clearest way to picture the limitations in the mental organization of a fish is to sum up, as Professor Sanford does, some characters in which the fish differs from man:

> No fish is ever conscious of himself; he never thinks of himself as doing this or that, or feeling in this way or that way. The whole direction of his mind is outward. He has no language and so cannot think in verbal terms; he never names anything; he

never talks to himself. As Huxley says of the crayfish, he "has nothing to say to himself or anyone else." He does not reflect; he makes no generalizations. All his thinking is in the present and in concrete terms. He has no voluntary attention, no volition in the true sense, no self-control.

The food of the young perch at first consists entirely of small, delicate crustaceans, such as *Cyclops* and its allies; from the time the perch are about an inch and a half in length they begin to add insects to the bill of fare. Adult perch have a still more varied diet, consisting of the larger crustaceans, mollusks, and other fishes. The young are gregarious, and those of about the same size tend to keep together, so that every farmer boy knows his chances of catching "a big one" are small indeed when he has his hook in a swarm of little fishes. He has, however, this consolation, — that the supply of the one size is likely to last; for

> Perch, like the Tartar clans, in troops remove,
> And, urged by famine or by pleasure, rove;
> But if one prisoner, as in war, you seize,
> You'll prosper, master of the camp, with ease
> For, like the wicked, unalarmed they view
> Their fellows perish, and their path pursue.
>
> OPPIAN, Halientica

CHAPTER XXX

THE ALLIES OF THE PERCH: PISCES

Halcyon prophecies come to pass
In the haunts of bream and bass.

MAURICE THOMPSON

Definition of Pisces (Lat. *piscis,* "fish"). The perch is a member of the class Pisces. Fishes are cold-blooded vertebrates, adapted to life in the water. In the lower forms the notochord persists as a continuous rod; in the higher fishes it is replaced by the vertebræ. The body is covered with a skin, in which are numerous mucous glands. Scales are usually present, set in pouches in the skin. In the great majority of forms, gills are the only organs of respiration. Locomotion is usually effected by means of fins. With very few exceptions, fishes lay eggs from which the young are hatched; that is, they are oviparous. Some of the sharks as well as some of the higher fishes produce living young.

Sharks and Rays. The sharks and rays, or Elasmobran′chii (Gr. *elasmos,* "metal plate"; *branchia,* "gills"), are fishes with a cartilaginous skeleton and with gills which communicate with the surface by several openings, instead of being covered by an operculum, as in the perch. The tail is usually unequally lobed, the dorsal division being the larger.

The sharks (Fig. 163) are, with the exception of one species found in Lake Nicaragua, marine animals, and are developed to the greatest extent in the tropics. The rays, or skates, are more flattened forms, adapted to a life on the bottom of the sea, which they often resemble in color. Fig. 164 shows a species common on the North Atlantic

coast, which grows to be about two feet in length. The most famous of the rays are the torpedoes, so called from

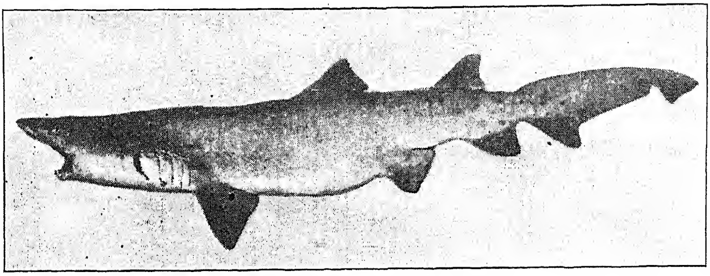


FIG. 163. Photograph of a shark
American Museum of Natural History

their power of giving an electric shock. One species is sometimes found on the eastern coast of the United States.

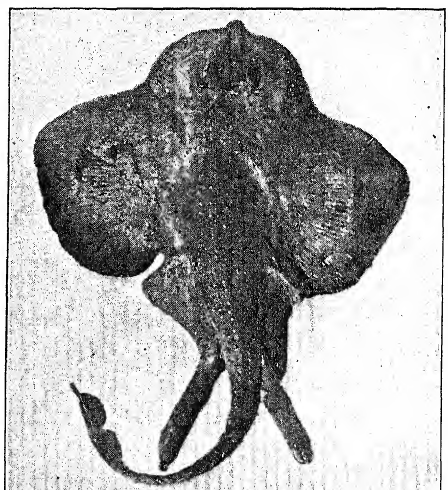


FIG. 164. Photograph of a skate

Economic Importance of Sharks. In some lands, sharks, and especially their fins, are considered a delicacy. Some species are used in producing leather for the manufacture of novelties. The shagreen, used in the arts for polishing woods and for ornamental work, is made from the skin of sharks. Their livers produce oils, and the bodies are used in the manufacture of fertilizer. But these uses do not offset the damage with which the sharks are charged. They destroy great

numbers of valuable food fishes and lobsters, and are a great bother to the set lines and nets of commercial fishermen.

Bony Fishes. The bony fishes, or Teleos'tomi (Gr. *teleos*, "complete" or "perfect"; *stoma*, "mouth"), in the higher forms, of which the perch is an example, have the skeleton ossified (converted into bone) and the body usually covered with scales (Fig. 165); in the lower forms the body may be covered with bony plates, and the skeleton may be hardly more ossified than in the group which has just been considered. In all teleostomes, however, the gills open beneath a protecting operculum. Most of our present-day fishes belong to this order.

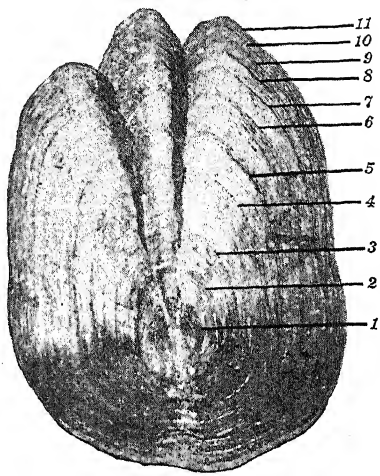


FIG. 165. A scale from a muskellunge. (Greatly enlarged)

The numbered rings are annual growth rings, showing that the fish bearing this scale was in its eleventh year. (Photograph by Dr. Alvin R. Cahn)

The gar pikes of American waters illustrate one type of body covering, consisting of bony, enameled, closely set plates, which form a complete coat of armor. The sturgeons (Fig. 166) illustrate another type, in which the armor is greatly reduced, the teeth absent, and the animals adapted to bottom feeding by the development of a beak, and by barbels for feeling for their food in the mud. Sturgeons are found in Europe as well as in the United States and Canada. One of the European species grows to be over twenty feet long.

The remaining bony fishes have fully ossified skeletons. The eels are forms in which the body is greatly elongated

and the scales reduced to almost invisible rudiments. Locomotion is effected by snake-like movements of the body. The common eel (*Anguil'la chrys'ypa*) of North America is found along the Atlantic coast from Newfoundland to Central America, and in most streams and ponds in the Eastern states which are accessible from the sea. The young are hatched at or near the surface of the ocean. They are so entirely different from the adult eel that for a long time they were thought to be a distinct genus of fish. After about a year

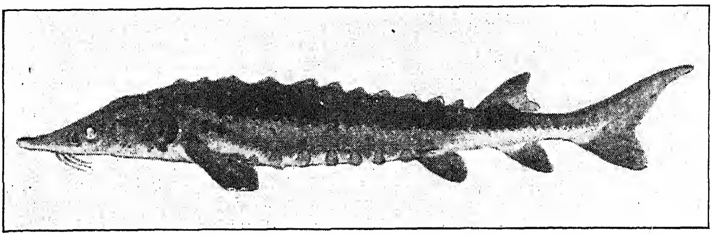


FIG. 166. A sturgeon[1]

of life in the ocean waters, drifting here and there without feeding, they find their way in countless numbers up the various streams. Here they complete their development and return to the sea to spawn. After providing for the new generation the adult eels die, never returning to fresh water.

Life of the Salmon. David Starr Jordan of Stanford University is one of the world's greatest authorities on fishes. He states, "Of all the families of fishes, the one most interesting from almost every point of view is that of the *Salmonidæ*, the Salmon family." There are several species of salmon on the Pacific coast and one species on the Atlantic. In 1925 the salmon canneries, especially in Oregon, Washington, and Alaska, produced canned salmon of more than $47,000,000 value. This is just about one half of the value of the total canned-fish industry of the entire country.

[1] From *The Fishes of Illinois* by Forbes and Richardson.

The adult salmon live in the ocean. When sexually mature they leave the ocean and by way of the rivers seek lakes and streams as spawning grounds. It seems fairly certain that the adult fishes return to the same waters where they were born. The mature salmon which escapes the fisherman makes its way upstream, frequently for several hundred miles. No food is taken after the fish enters fresh water.

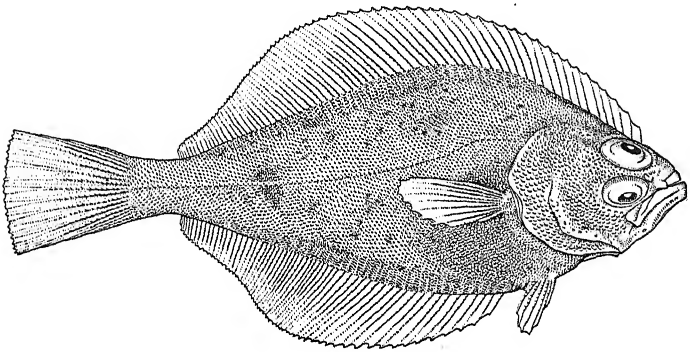


FIG. 167. Flatfish

From *Report of Fur-Seal Investigations*

It seems to have but one object, that of reaching the breeding grounds. Waterfalls and even some types of dams do not deter the migration, for by persistent effort some individuals finally succeed in leaping over such obstacles. After the eggs have been laid and fertilized the adults of both sexes die, never living to return to the sea. From the spawning grounds the young salmon migrate to the sea, where they live for from three to five years before becoming mature and ready to ascend the streams to the breeding grounds.

Flatfishes. The flatfishes (including among other fishes the flounders and halibuts) are a family of compressed fishes, dark on one side and light on the other, which lie on their light side on the bottom of the sea (Fig. 167). When

thus placed the dark surface is protectively colored and the eyes are both on the upper side, which is sometimes the right side and sometimes the left side of the body. When they are hatched they have an eye on either side and they swim like other fishes, though with a slight leaning to one side, which becomes more and more marked as they develop, till they finally turn entirely over. The eye on the light side has meanwhile worked its way slowly round to the dark side, where it remains with its fellow, looking upward when the fish lies on the bottom.

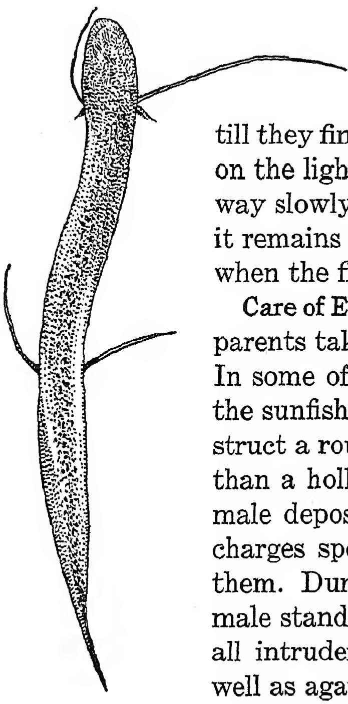


FIG. 168. Lungfish
After Dean

Care of Eggs and Young. In most fishes the parents take no care of the eggs or young. In some of the fresh-water fishes, such as the sunfishes, for example, the males construct a rough nest which is often no more than a hollow in the gravel. Here the female deposits her eggs and the male discharges sperm into the water to fertilize them. During development of the eggs the male stands guard to defend them against all intruders, even against the female as well as against outside enemies.

Lungfishes. The lungfishes (Fig. 168), or Dip′noi (Gr. *di-*, "two"; *pnoe*, "breath"), in place of the air bladder have a true lung, or pair of lungs, opening from the ventral side of the alimentary canal. Dipnoans differ from other fishes, too, in the fact that the heart is incompletely divided into three chambers. These animals are interesting as the possible ancestors of the toads, frogs, and their allies, which we shall consider later. Though numerous in earlier times there are

but three genera now in existence, one each in the rivers of Queensland (in Australia), Brazil, and tropical Africa.

Economic Importance of Fishes. The value to a people of an abundant and cheap fish supply cannot be overestimated. Recognizing its importance, the United States government has long maintained a Bureau of Fisheries, which has been active along both practical and scientific lines. A very extensive laboratory is maintained by the Bureau of Fisheries at Woods Hole, Massachusetts, for the study of marine life. Much of the work on problems of fresh-water life has been carried on by the Bureau through its laboratory on the Mississippi River, at Fairport, Iowa. Among the subjects which are considered by the Bureau are the resources of our inland and coastal waters, the geographical distribution of the economically important fishes inhabiting them, and the study of the natural history of fishes, their enemies, diseases, and the remedies therefor. Perhaps most important of all, it has carried on the artificial propagation and distribution of valuable species. According to statistics for 1925 more than 191,000 persons in the United States and Alaska are engaged in fishing as a business. They receive close to $98,000,000 annually for their products.

Hatcheries have been established in many places for rearing the young from fish eggs. In these hatcheries eggs are gently pressed from the bodies of mature fishes, or gathered from the nests where they are deposited in ponds and streams. The fertilized eggs are placed in jars of water through which a small water current is passed, or in wire-bottom trays set into troughs of running water. The young fishes after hatching are kept in troughs and ponds until they are ready for transplanting to the lakes and rivers. Until very recently fishes were liberated when but a few inches long. The result was that many were destroyed by larger fishes. A very recent plan of operation calls for fish nurs-

eries to carry the young fish for a few months after they leave the hatcheries to insure their ability to care for themselves when transplanted to the lakes and streams.

Some idea of the extent of the operations conducted to restock our streams and lakes is given by the fact that more than five billion fish and fish eggs were distributed by the United States Bureau of Fisheries in 1926.

FIG. 169. Inshore with the haul of a large commercial seine on the Mississippi River

Protection and Conservation. Most states have definite laws for the protection of fishes. When these laws are wisely formulated and obeyed they protect the fishes at the breeding season and regulate the methods of catching. The game fishes, especially the black basses and various species of trout, are very generally protected from commercial fishing and are thus preserved for the disciples of Izaak Walton. In most regions the game fishes may be taken only by hook and line and their sale is forbidden. Another conservation measure is the protection of many species by making it illegal to take

fish below certain lengths. In some locations the numbers allowed each fisherman per day are limited.

Power dams and pollution of the streams by sewage and factory wastes are probably the greatest factors in reducing the fish population of our streams. Public sentiment against, and knowledge of, these destructive conditions are necessary before adequate laws may be passed and enforced to protect the life of our streams. There are many very worthy organizations whose chief object is the enlisting of public sentiment in favor of conservation. Some states set apart streams as fish refuges. In these refuges fishing is either prohibited or very rigidly restricted.

The lives of many thousands of fishes are saved annually by the rescue crews operating in the backwaters after streams have been flooded. The relation of this rescue work to mussel propagation was mentioned on page 205.

Indirect Value of Fishes. In judging the value or importance of the various kinds of fishes their use as food for man is not the only relationship to be considered. The gizzard shad (*Doroso'ma*) is rarely used for human food. Yet in many streams it is very abundant, living very largely on microscopic plants and animals. In turn it serves as one of the most abundant food supplies of game fishes, which are unable to use the food upon which the gizzard shad thrives. Other species are noteworthy because of their destructive habits. The gar pikes are outlaws, for they have voracious appetites and live almost wholly on small fishes and the young of species which are valuable as food for man.

Mosquito Control by Fishes. Goldfishes and several species of minnows feed very largely on insect larvæ. In many regions where ponds and swamps are the breeding places of hordes of mosquitoes the mosquito problem has been solved by introducing goldfishes, and minnows (especially of the genus *Gambu'sia*), into the water.

Geographical Distribution of Fishes. A simple and seemingly natural classification of fishes, as regards their habitat, is a division into fresh-water and marine forms. This will serve our purpose if it be remembered that there has been much interchange of species between the two.

There are three common divisions of the ocean fauna, — the *littoral*, or shore fauna, the *pelagic*, or open-sea fauna, and the *abysmal*, or deep-sea fauna. The shore fishes never venture far into the open sea. Among them are to be included the large members of the salmon family already referred to. The pelagic fishes are mostly hunters of other animals in the sea and are strong swimmers, as befits their environment. Typical fishes of this type are many of the sharks.

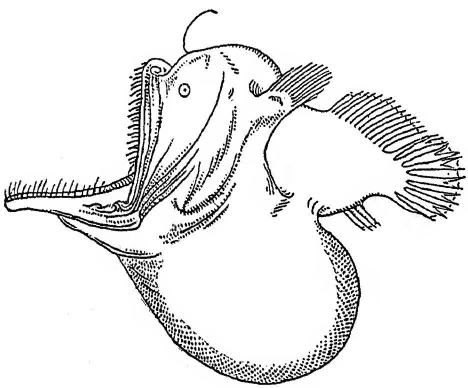


FIG. 170. A deep-sea fish[1]

The most peculiar forms belong to the deep-sea fauna. There, of course, the conditions are unusual; life must be adapted to an enormous pressure, to a low temperature (not far above freezing), and to absolute darkness, except where it is lit up by some phosphorescent animal. Hence the fishes found in the deep waters are most bizarre, characterized by uniformity of color pattern, often black, though brighter colors are sometimes developed; by modifications of the eyes, which are either very large in proportion to the size of the fish or entirely absent; by the development of tactile

[1] From Gunther's *Fishes*.

and phosphorescent organs. Increase in size of mouth, jaws, and stomach enables the fish to swallow an animal larger than itself. Fig. 170 shows one of these species.

Fishes of Past Ages. The earliest known remains of vertebrates are those of fossil fishes. The oldest of the fossil fishes were covered with a heavy shell, or armor, and in appearance somewhat resembled arthropods. These fossil

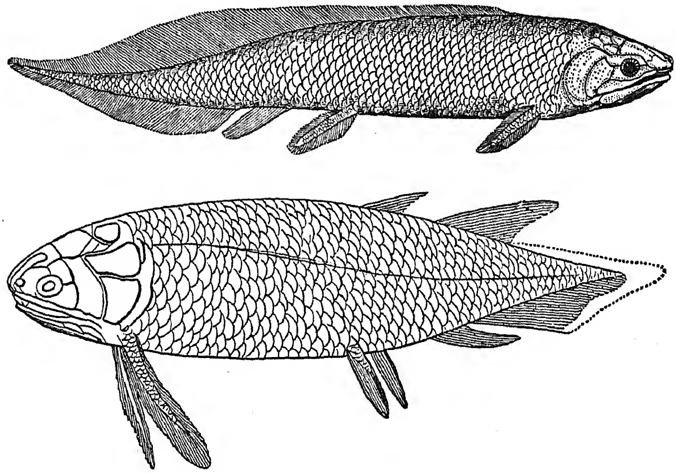


FIG. 171. Two examples of fossil fishes

fishes are found in rocks of that period of the earth's history which is known as the Age of Invertebrates. Geologists very commonly call the following age the Age of Fishes, for then many different kinds of fishes made their appearance. Some of these were not very different from present-day fishes (Fig. 171), while others represent groups unlike any that exist today. Paleontologists tell us that fishes first appeared on the earth about twenty-five million years ago. At that time they were the highest animals on the face of the earth. But we should hardly recognize as fishes some of the species of that day.

CHAPTER XXXI

THE GREEN FROG

Cardanus undertakes to give reason for the raining of *Frogs*; but if it were in my power, it should rain nothing but Water *Frogs*, for those, I think, are not venomous. — IZAAK WALTON, The Compleat Angler

Habitat and Distribution. The green frog (*Ra'na clam'-itans*, Fig. 172) is one of the commonest species of frogs in the eastern United States. It frequents the neighborhood of springs and meadow brooks and may be distinguished from its larger relative, the bullfrog (*Rana catesbia'na*), by the presence of two glandular folds of skin along the sides of the back.

In many regions the most abundant frog is a smaller species commonly called the leopard frog (*Rana pip'iens*). The following descriptions of structure agree equally well for bullfrog or leopard frog, though the green frog is the species actually described.

External Structure. The body is divisible into a *head* and *trunk*; there is no visible tail. The body covering is a soft, smooth *skin* without scales, abundantly supplied with mucous glands. There are two pairs of appendages, — the *limbs*: the anterior of which are divisible into *upper arm, forearm,* and *hand*; the posterior, into *thigh, lower leg,* and *foot.* The hand ends in four short *fingers*; the foot, in five *toes*, joined by a web. Both fingers and toes are often spoken of as *digits.* The *eyes* are situated prominently on the top of the head, and possess, in addition to an upper eyelid, a thin fold of skin called the *nictitating membrane,* which can be drawn across the eyeball from below. There is no true

lower eyelid. In front of the eyes, near the anterior end of the head, are the external openings of the *nostrils*; posterior to the eyes are smooth, round spots, the *tympanic membranes,* which are the outer portions of the frog's ears.

The Digestive System. The wide *mouth cavity* (Fig. 173) narrows into the short, straight *esophagus.* Conical *teeth* are placed along the edge of the upper jaw and on the roof

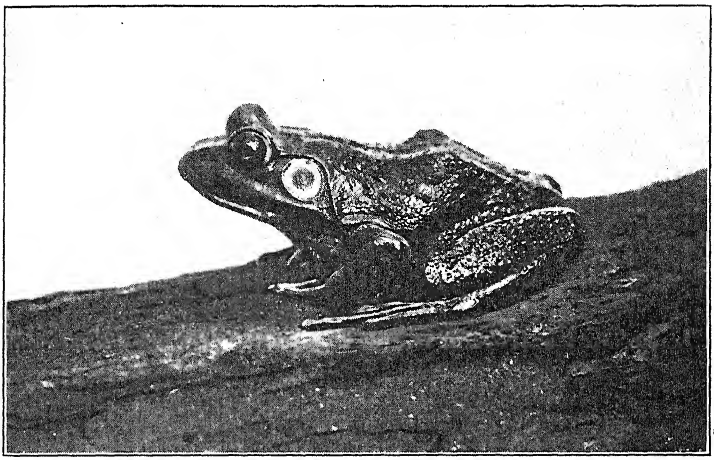


FIG. 172. The green frog. (Reduced)

Photograph by Elwin R. Sanborne, courtesy of the New York Zoological Society

of the mouth. A thick, fleshy *tongue,* notched posteriorly, is attached by its anterior margin to the ventral surface of the mouth cavity. The tongue can be thrust out suddenly to quite a distance to capture food, which consists largely of insects, worms, and mollusks. Two openings lead from the mouth to the nostrils, and two openings (the Eustachian tubes, Fig. 173) communicate with the ears. The *stomach* is a thick-walled sac tapering gradually into the coiled *small intestine.* Beyond the small intestine the alimentary canal suddenly increases in diameter, forming the *large intestine,*

or *rectum,* which passes without change of diameter into the terminal *cloaca.* Between the lobes of the *liver* lies a large *gall bladder.* Another gland, the *pancreas,* also furnishes a digestive fluid. The *spleen* is red and globular.

The Circulatory and Respiratory Systems. The *heart* inclosed in its sac, the *pericardium* (Fig. 173), has one chamber more than the heart of the perch, by the division of the auricle into two parts, a *right* and a *left auricle.* The blood is aërated in the *lungs,* the walls of which are traversed by the capillaries of the blood system. The lungs communicate with the exterior by means of the windpipe, or *trachea,* opening into the mouth by a narrow slit, the *glottis.*

Owing to the additional chamber in the heart and the presence of lungs, the course of circulation in the frog is somewhat different from that in the perch. The aërated blood returned from the lungs by the pulmonary veins is poured into the left auricle; the nonaërated blood from all over the body is returned to the right auricle. The auricles contract at the same instant, forcing both venous and arterial blood into the ventricle, which in turn contracts before there has been much mixing of the two kinds of blood, emptying its contents into the arterial circulation, the beginnings of which are shown in Fig. 173. As the arterial system takes its rise from the right side of the ventricle, the first blood to enter the arteries is nonaërated. Owing to the less pressure in the arteries which supply the lungs and skin, and the presence of valves which cut the blood off from easily entering the arteries that supply the head and body, most of the nonaërated blood goes to the lungs and skin. The blood which follows is a mixture of aërated and nonaërated blood. When the pressure is raised by the presence of nonaërated blood in the capillaries of the lungs and skin, this blood forces the valves aside and makes its way to the different parts of the body, except the

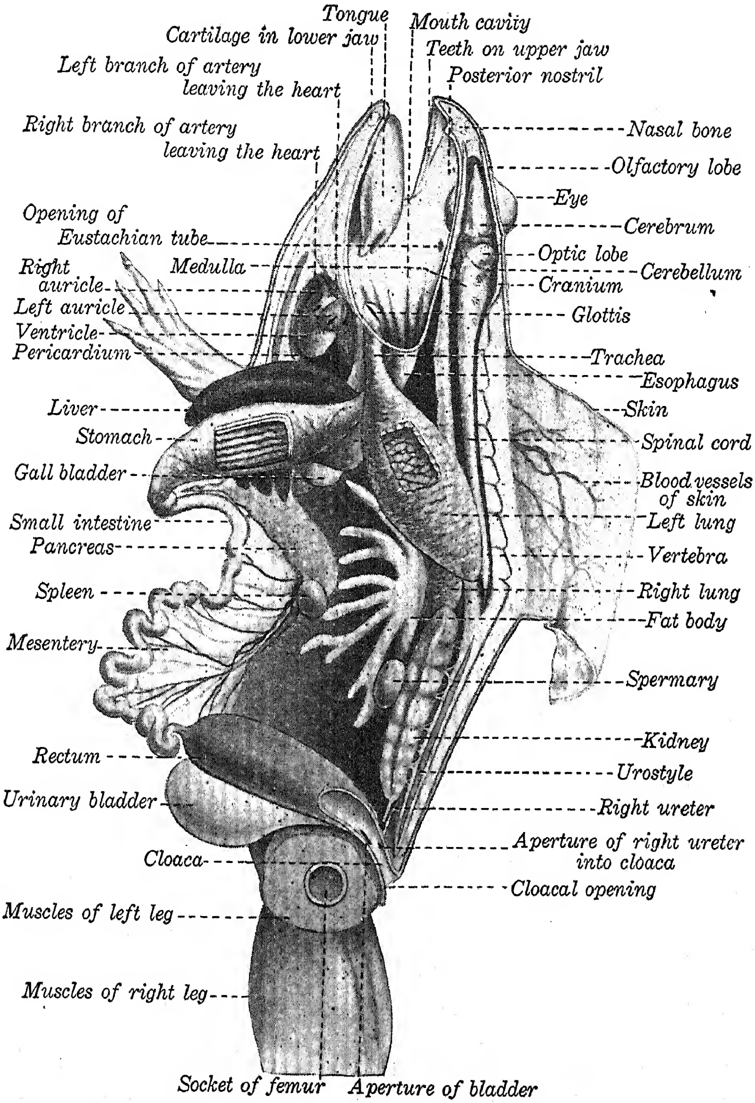


FIG. 173. Dissection of the green frog. (Enlarged)

head. In the course of the artery leading to the head is a structure (the carotid gland) which temporarily obstructs the flow of blood till the body arteries have become filled. The supply of mixed blood having become exhausted, the head receives only aërated blood. The impure blood from the organs of the body cavity and from the hind legs returns either through the liver or the kidneys; while that from the head, the forelimbs, and from the skin and muscles generally, is poured directly into the right auricle.

The frog breathes with the mouth closed. By depressing the tongue, air is drawn into the mouth cavity through the nostrils. When the tongue is raised the nostrils close by valves and the air is forced into the lungs. Considerable exchange of gases takes place through the soft, moist skin, which is well supplied with blood vessels.

The lymphatic system is well developed in the frog, and the lymph is assisted in its circulation by two pairs of *lymph hearts*, one at the posterior end of the body, and one in the region of the shoulders. The pulsations of the posterior lymph hearts can be observed externally in the living frog.

Excretory System. The *kidneys* (Fig. 173) are a pair of oval, dark-red bodies lying in the dorsal part of the body cavity. The *ureters* open from them into the cloaca. The *urinary bladder* is a large, thin-walled sac projecting ventrally from the cloaca and is a very different organ from the urinary bladder of the perch, which is a dilatation of the ureter. The function of the two organs, is, however, the same, that of receiving the liquid nitrogenous waste from the kidneys.

The Skeletal System. In general, the skeleton of the frog (Fig. 174) is built upon the plan seen in the perch, but its appendages are considerably more specialized. The *skull* is flattened and the *cranium* articulates with the first vertebra by two rounded contact surfaces, or *condyles*. The

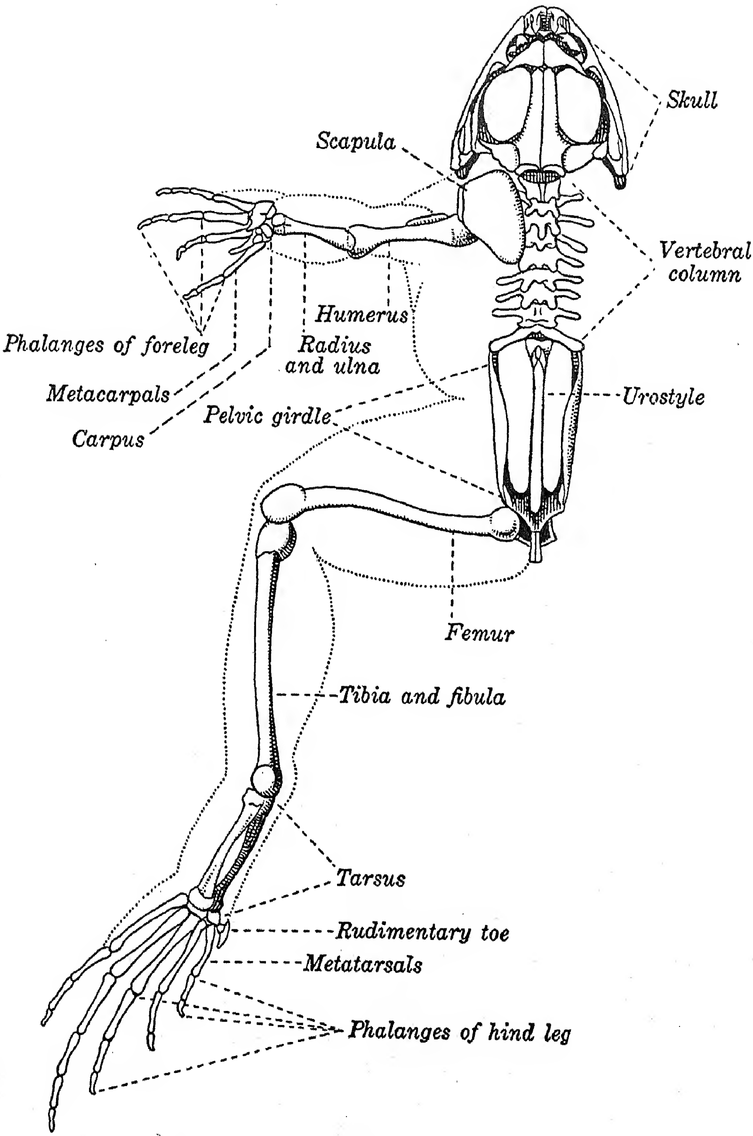


FIG. 174. Skeleton of frog. (Natural size)
Modified from Duges

vertebral column consists of nine vertebræ, terminated by a long bone called the *urostyle* (tail bone).

The bones of the arms are attached to a *shoulder girdle* consisting of the shoulder blades, or *scapulæ*, two *coracoids*, and two collar bones, or *clavicles*. A broad breastbone (*sternum*) extends a short distance along the median ventral line. Each of the anterior limbs contains one bone in the upper arm, called the *humerus*; one bone in the forearm, composed of two bones united, — the *radius* and *ulna*; six bones in the wrist region, or *carpus*; four complete sets of bones in the palm (*metacarpals*); and four complete sets of finger bones (*phalanges*). The metacarpals and phalanges of the inner digit are rudimentary.

The leg bones are attached to the vertebral column by means of a *hip* or *pelvic girdle*, of peculiar shape. The skeleton of each leg consists of one bone in the upper leg, the *femur*; one bone in the lower leg, formed from two bones united, the *tibia* and *fibula*; five bones in the ankle region, or *tarsus*; and five complete sets of *phalanges*. A sixth rudimentary digit is also present, consisting of one metacarpal bone and two phalanges.

The Nervous and Muscular Systems. The nervous system is similar in general plan to that of the perch. The *brain* has large cerebral hemispheres (*cerebrum*, Fig. 173), each of which is prolonged anteriorly into an *olfactory lobe*. The *optic lobes* are also large, but the *cerebellum* is small. Behind the cerebellum is the *medulla oblongata*, at the posterior end of which the *spinal cord* arises. The *nerves* are not shown in the dissection. The *muscles* are arranged in bands, or spindle-shaped masses, instead of in segments, and the frog is capable of much more complex movements than the perch.

The Reproductive System. The *spermaries* of the male frog (Fig. 173) are bean-shaped bodies lying beneath the kidneys, to which they are attached. The *ovaries* of the

female frog when mature fill a large portion of the body cavity. Attached to the anterior end of the spermaries and ovaries are the *fat bodies,* — lobed organs which attain their fullest development in the spring. These organs are believed to be of use as storehouses of reserve material, rendering possible the formation of large numbers of spermatozoa or eggs without complete exhaustion of the animal. After the spawning season the fat bodies decrease in size.

Development. The eggs of frogs (Fig. 175) are laid early in the spring in shallow water in large, jelly-like masses. They are fertilized by the male as they leave the body of the female. Within a week or ten days they hatch, the time required depending largely upon the temperature of the water. At first the young is blind, and is without gills or a mouth; it fastens itself to weeds and other objects in the water by means of a crescent-shaped, adhesive apparatus at the anterior end. Certain areas of the body are covered with cilia, by the vibration of which the animal is able, even without using its tail, to go forward in the water. Eyes, external gills, and a mouth provided with horny jaws soon appear, and the young, now the familiar tadpole, begins to feed on plant food. The alimentary canal is long and coiled, as it usually is in animals which feed upon plant material. The heart has two chambers.

As the tadpole increases in size the first, or primary, gills are replaced by secondary gills, which soon become covered with a fold of skin, the *operculum.* The growth of the operculum continues till the gill openings are covered, leaving a small hole usually on the left side. In this fish-like condition the tadpole continues through the summer, and on the approach of cold weather buries itself in the mud, where it hibernates. In the leopard frog and some other species the tadpole develops into the adult form in the course of a single season.

If the adult condition has not been reached, the tadpole continues its growth the following summer. The hind legs appear and grow to be about an inch long, when the fore-legs suddenly appear. The front legs are really formed as early as the hind legs, but they are kept beneath the skin

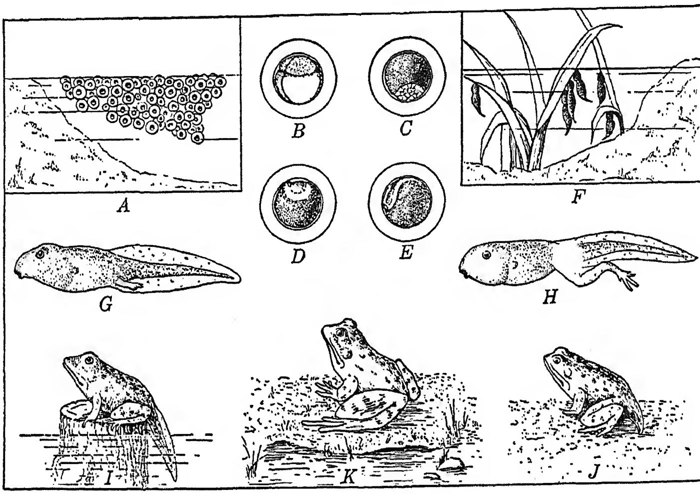


FIG. 175. Development of a frog[1]

A, eggs in water; *B* to *E*, stages in the division of the egg and arrangement of the cells to form the embryo; *F*, recently hatched tadpoles clinging to water plants; *G* and *H*, full-grown tadpoles with hind legs developing; *I* and *J*, transformation of tadpole into adult form showing gradual loss of tail; *K*, fully formed frog

for a while. The broad and compressed tail, which forms the tadpole's chief organ of locomotion, is gradually absorbed, and the young frog finally hops out on land with only a stump of a tail remaining. In the time these changes have been taking place externally, important changes have gone on inside: the gills have been replaced by lungs; one

[1]Reprinted by permission from *Textbook of General Zoology*, by W. C. Curtis and M. J. Guthrie, published by John Wiley & Sons, Inc.

of the chambers of the heart has been divided; the intestine has become shorter, fitting the frog better for an animal diet; and the horny jaws have given place to a wide mouth with teeth. This metamorphosis is retarded by cold and accelerated by rest and freedom from disturbance of the water. The frog grows for several years without further metamorphosis, except the gradual disappearance of the stump of the tail. Throughout life the outer skin is cast periodically in a single piece and immediately devoured.

Tadpoles fed on thyroid gland transform to frogs long before their natural time, and tadpoles from which the thyroid is removed by an operation never undergo metamorphosis.

Relation to Environment. The dark-green and brown colors of the upper surface afford considerable protection among the water plants and along the muddy or grassy margins of ponds and streams, and the white under surface may be similarly useful in the water.

The green frog is a voracious feeder and varies its diet with almost every kind of small creature that comes its way, not hesitating in the least to devour smaller individuals of its own kind. Usually only moving objects are seized, and it has been said that the frog may starve to death in the midst of an abundance of food if there is no movement to attract its attention. The eyes are situated high on the top of the head, where they maintain a wide survey. Every boy in the country knows of the difficulty of approaching these alert creatures, and he knows, too, how to capture them by dangling a hook with a piece of red flannel in front of them. Even if well fed the frog seems to find the moving object irresistible, and seizes it with wide-open mouth. The tongue is covered with a sticky substance and can be swiftly extended with unerring aim to a distance of several inches.

While the frog depends very largely on the sense of sight to warn it of approaching enemies or enable it to distinguish food, the sense of hearing is also of considerable value. Dr. R. M. Yerkes of Yale University, who has studied the sense of hearing in frogs both in the laboratory and in the field, says that he is convinced that sounds which are of importance in the life of the animal, as the splash made by a frog jumping into the water, are not only heard, but that such sounds serve to put other frogs on their guard. The croaking of male frogs in the spring is undoubtedly heard by the female and serves to make mating more certain.

The observer just cited does not give the green frog credit for much intelligence, since his experiments seem to show that nearly all the frog's actions are repeated with machine-like accuracy, and new habits are learned very slowly. He is inclined to think that even the perch learns more rapidly than the frog. He also notes that the frog is very timid, and that fright tends to lengthen the process of learning.

When suddenly touched, the frog may do one of several things: it may jump, using the strong hind legs sometimes with force enough to carry it several feet; it may remain perfectly quiet; or it may crouch with its head close to the ground, at the same time puffing itself out. This last action, Dr. Yerkes has noticed, more often takes place when the animal is touched in front and is probably useful to render seizure difficult, or to prevent it altogether. If the frog leaps away, it is usually into the water with a loud "plunk." A few swift strokes of the hind legs serve to carry the animal to shelter beneath protecting débris in the water. There it is able to remain for a considerable period without the necessity of rising to the surface for oxygen, owing to the low state of all its life processes. The frog has numerous enemies, among which are owls, hawks, and herons,

many snakes and other reptiles, and several fur-bearing creatures which come to the water in search of food.

During the winter, green frogs, like some other frogs, hibernate in the mud at the bottom of pools. With returning spring they congregate to lay their eggs, and the males may then be heard calling to the females in an unmusical "chung," "chung," which is not as familiar a sound, perhaps, as the bass voice of the bullfrog or the high-pitched, insistent note of the spring "peepers." After providing for the reproduction of the species, the green frog spends the rest of the summer in its rather solitary life on the bank of some stream or spring hole.

CHAPTER XXXII

THE ALLIES OF THE FROG: AMPHIBIA

Blue dusk, that brings the dewy hours,
  Brings thee, of graceless form in sooth
Dark stumbler at the roots of flowers,
  Flaccid, inert, uncouth.

EDGAR FAWCETT, A Toad

Definition of Amphibia (Gr. *amphibios,* "capable of living in both air and water"). The frog belongs to the class Amphib′ia, to which belong also the toads, newts, and salamanders. Amphibians are cold-blooded vertebrates covered with a smooth or rough, moist skin, in which are numerous mucous glands. In the immature state most amphibians are adapted to a life in the water and breathe by gills; when adult the gills are in the majority of cases absorbed, and the animals breathe by lungs. Four limbs are usually present. Nearly all amphibians lay eggs, from which the young develop.

Two out of the three orders into which the class is divided will be discussed here. One of these orders includes the salamanders and newts, the other the toads and frogs.

Salamanders and Newts. The Urode′la (Gr. *oura,* "tail"; *delos,* "conspicuous") are elongate forms, with a tail throughout their lives. They are often, but erroneously, called lizards, and resemble the latter only in external form. The eggs are laid usually in the water in strings, or in large masses resembling frogs' eggs, or singly, attached to the leaves of water plants.

The red-backed salamander (*Pleth′odon cine′reus*) and a number of other species spend their entire life in moist

places, under logs and stones. They do not even go to the water to lay their eggs but deposit them among moist leaves and in rotten wood. Salamanders and newts hatch as tadpoles, which develop into the adult form without a strongly marked metamorphosis. The young of most species may be distinguished from the tadpoles of the toad, and from those of our various species of frogs, by their more elongate form. The gills are usually visible externally for a longer period than is the case with the toad and the frogs. Some species retain their gills throughout life, though the lungs are also functional; in others, though the gills are absorbed in adult life, the gill openings are retained; in still others all traces of gills and gill slits disappear; and, finally, a few species lose their lungs also, when mature, depending entirely upon the skin for respiration.

The genus *Ambys'toma* includes some of the largest of our species, known by the common name of blunt-nosed salamanders. The color is black, spotted with yellow. As these salamanders are protected by an acrid secretion from the mucous glands of the skin, the conspicuous colors are possibly to be interpreted as warning coloration. The adults live in damp places and lay eggs in the water in large masses resembling frogs' eggs, though the jelly-like mass which surrounds them is more opaque. The young keep their gills for a considerable period, and one species (*Ambystoma tigri'num*) may even breed in the gill-bearing larval stage. These immature forms, called the axolotl, live in the water, growing to be eight or nine inches long, or, in exceptional cases, even larger, and may continue in this condition for years, without ever changing to the adult form.

Like some other amphibians these salamanders can regenerate lost limbs. This, according to Professor Gadow of Cambridge, England, takes place more certainly and quickly the younger the animal is. In one case quoted by this

authority the hand of an axolotl ten years old was removed, and it was replaced within twelve weeks.

The newts, or tritons, are carnivorous salamanders which are more or less aquatic in their habits when adult, or, at least, during the breeding season, at which time also the colors of the males in some species become brighter, and a crest is developed along the back. The common species of the eastern United States (*Tritu'rus virides'cens*, Fig. 176) is olive green or reddish in color, with a compressed tail and a row of small orange-colored spots along the right and left

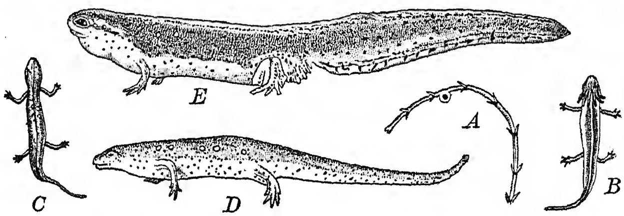


FIG. 176. Development of newt. (Reduced)

A, egg on water plant; *B*, larva, in August; *C*, young, in autumn; *D*, about two years old; *E*, adult. (After Gage)

sides of the body. It grows to the length of three and a half inches. The eggs (Fig. 176, *A*) are laid during April, May, or June, usually in the axils of leaves of water plants, and the leaves are drawn together and made into a compact mass by a secretion from the oviduct. As a general rule one egg is laid at a time; occasionally two are inclosed in the same mass. The young hatch in from twenty to thirty-five days, depending on the temperature. In August they resemble Fig. 176, *B*. Late in the fall they leave the water and live on land in damp places beneath logs and leaves in the woods. They are then of a beautiful red color and have a cylindrical tail (Fig. 176, *C*). Several years are required to produce the aquatic adult form (Fig. 176, *E*), which, as will be seen, differs considerably from the young.

The mud puppy, or water dog (*Nectu'rus* Fig. 177), lives permanently in the water and never loses its gills. This form is the most primitive of present-day amphibians. The adults are more than a foot in length.

Toads and Frogs. The members of the order Anu'ra (Gr. *an-*, "without"; *oura*, "tail") undergo a well-marked metamorphosis. From eggs they hatch as tadpoles, and

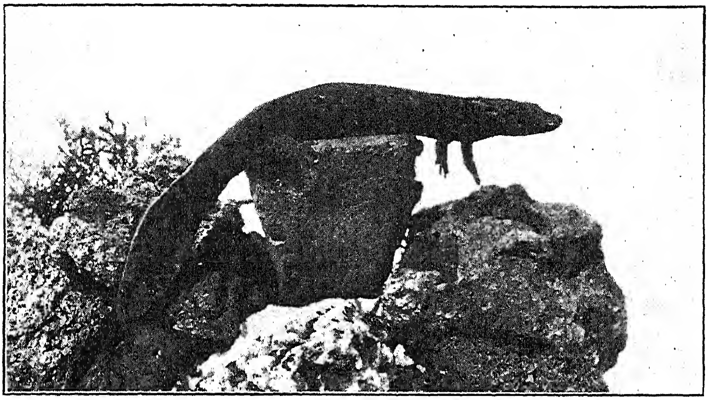


FIG. 177. *Necturus* in an aquarium

Photograph by Elwin R. Sanborne, courtesy of the New York Zoological Society

later change to the adult condition by the development of legs and the gradual absorption of the tail (Fig. 175).

Many examples of peculiar breeding habits are known. The female of a Brazilian species of tree frog (*Hy'la fa'ber*) lays her eggs within a circular wall of mud which she constructs on the bottom of a shallow pool of water. Within this nursery the tadpoles develop, unless liberated by the rain or other accident. Several species lay their eggs on the leaves of trees above the water, into which the young fall when hatched. The male of the obstetrical toad of Europe (*Al'ytes obstet'ricans*) winds the eggs around his legs, and, seeking a safe place, guards them till they hatch. In a

South American species, the famous Surinam toad (*Pi'pa pipa*), the eggs are spread by the male over the back of the female, where each egg becomes covered with a growth of skin, forming a pouch with a lid. Here development goes on, and the entire metamorphosis takes place within the egg. In a Chilean species (*Rhinoder'ma dar'wini*) the eggs are transferred by the male to vocal sacs at the side of the mouth, which become greatly developed at the breeding season. Metamorphosis takes place within these sacs, and the young escape in the adult condition. In half a dozen species of tree frogs from South America (*Nototre'ma*) the females possess dorsal pouches in which the eggs are placed. The young appear either as tadpoles or as perfect frogs.

The tree frogs, or tree toads, are forms adapted to life in trees. They possess soft pads on the ends of the fingers and toes. Many of them, like our common tree toad (*Hyla ver'sicolor*, Fig. 178), are protectively colored, and have the power of changing their color through various shades of gray and green. Several of our smaller species of tree toads, called "peepers" in the country, give utterance to shrill notes, which are among the first sounds of spring. In that season they seek the ponds to mate and lay their eggs.

The common toad (*Bu'fo americanus*) is one of the farmers' most valuable allies in the destruction of injurious insects. Usually the toads feed continuously throughout the night. It has been estimated that in a single night a toad consumes insects enough to equal four times the capacity of its stomach. Despite the prejudice which its appearance still excites among those who do not understand it, the animal is a most interesting object for study. There is no truth in the oft-repeated statements of its poisonous qualities, except in so far as the acrid secretion of the skin, which is a protection to many amphibians, might be injurious if it got on sensitive surfaces, such as the lining of

the eyelids. The dark-colored eggs are laid in long strings, like a string of beads, in shallow water, usually in April, in the latitude of New York. They hatch in two or three weeks into small black tadpoles, which transform and become minute toads within about two months.

Use as Food. Several different species of the larger frogs, the bullfrog and the green frog especially, are frequently caught for market. The hind legs of frogs are by many considered a great delicacy.

FIG. 178. Photograph of a tree frog on the bark of a tree. (Natural size).

Amphibians of the Past. Since the amphibians are the lowest animals having limbs similar to those of mammals, man has been much interested in their beginnings. The first fossil remains of amphibians date to that period of the earth's history when there was a very luxuriant growth of tropical fern-like trees. During this time there were many regions where movements of the earth's crust caused these forests to be covered by water and turned into coal. The swamps of that time are the coal beds of today, and the period is known as the *Carboniferous Age*, or *Age of Coal Plants*. Though fishes and many invertebrate forms were

abundant, progress had been made over preceding periods in the development of backboned creatures adapted to breathing air. These were amphibians, and from the prevalence of species of this order the period is often called the *Age of Amphibians*. There were snake-like forms without limbs, and forms with every degree of limb development. Some species grew to be as large as alligators of the present time.

This age when the amphibians represented the highest development of life upon the earth came to a close about the time that the Appalachian Mountains were being formed. Up to the close of this age the eastern portion of what is now the United States had undergone frequent changes of level. Part of the time the land areas stood well above the water, but the land was frequently overflowed by the sea. With the formation of the Appalachian Mountains, conditions became more permanently suited for land animals. In the following ages new forms of life began to come into existence.

CHAPTER XXXIII

THE PINE LIZARD AND ITS ALLIES: REPTILIA

I only know thee humble, bold,
Haughty, with miseries untold,
And the old curse that left thee cold,
And drove thee ever to the sun
On blistering rocks.

BRET HARTE, The Rattlesnake

THE PINE LIZARD

Habitat and Distribution. The pine lizard (*Scelop'orus undula'tus*, Fig. 179), or "swift" as it is often called, is found in the eastern United States as far north as Michigan, preferring the more sandy areas covered with pine. It is a graceful little creature about seven inches long, gray in color above, with faint undulating black stripes, and silvery white below. The male is ornamented with lustrous patches of blue or green, edged with black on the sides of the throat and under surface of the body. Old fences which border pinelands are favorite resorts, and here it pursues and captures countless insects. Like others of its kind this lizard loves the sun, and is to be found active only in the hottest part of the day. During the cold weather it hibernates, at least in the northern part of its range.

External Structure. The body is elongate in form, resembling that of the salamanders, but the skin is covered with scales instead of being smooth, and there are no mucous glands. The digits of the four legs are long and slender, and have sharp claws, which are admirably fitted for clinging to inequalities in the bark of trees. The gray color of the back is protective when the lizard is at rest, and its movements

are so quick that it is difficult for the eye to follow them. When alarmed the scales can be raised, the throat patches swollen, and the head elevated. The harmless little creature then looks quite formidable. In order to provide for growth the scaly skin is cast periodically.

Internal Structure. The internal structure is, in general, similar to that of the amphibians, but in several respects it

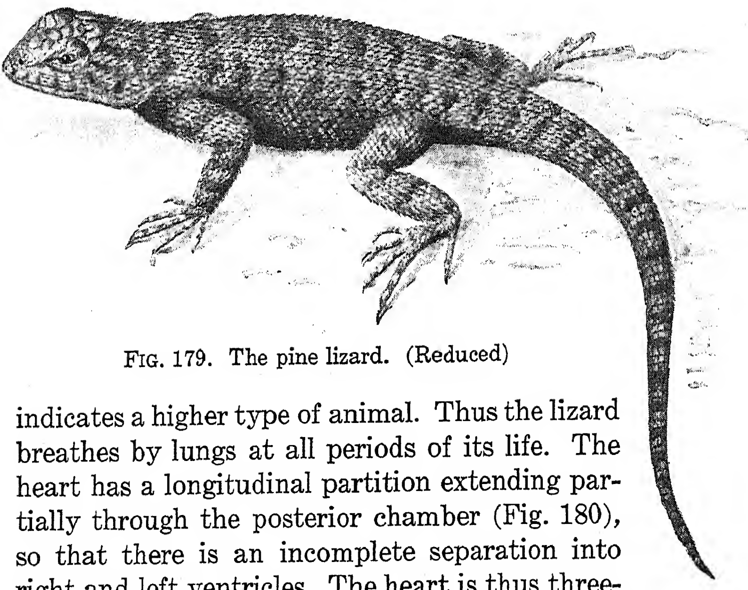


FIG. 179. The pine lizard. (Reduced)

indicates a higher type of animal. Thus the lizard breathes by lungs at all periods of its life. The heart has a longitudinal partition extending partially through the posterior chamber (Fig. 180), so that there is an incomplete separation into right and left ventricles. The heart is thus three-chambered, being composed of one ventricle and two auricles. The arteries leading out from the ventricles are so arranged that impure blood returning from the tissues of the body is not completely mixed in the ventricle with the purified blood from the lungs. When both auricles contract, the blood is forced into the ventricle. But the purified blood from the left auricle does not mix completely with the impure blood from the right auricle. Arteries which open from the left side of the ventricle receive most of the blood from

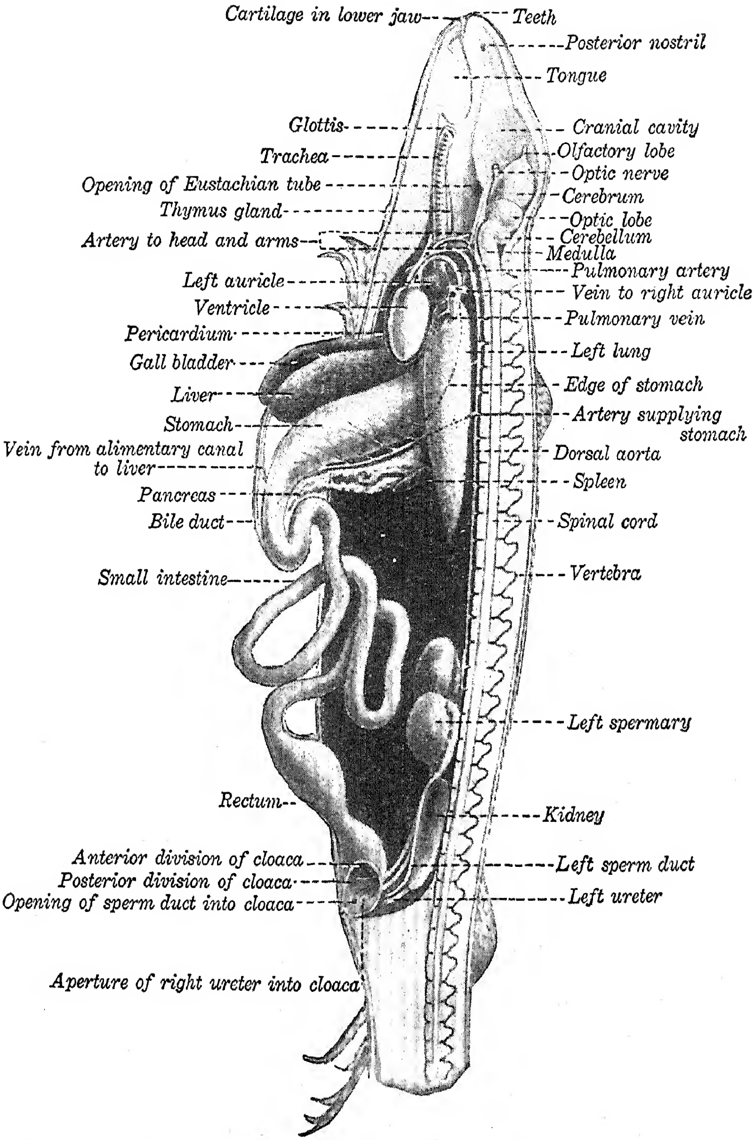


FIG. 180. Dissection of the pine lizard. (Enlarged)

the left auricle, and thus they carry aërated blood almost exclusively to the tissues of the body. In similar manner when the impure blood from the right auricle enters the ventricle most of it is forced directly into the pulmonary artery, which carries it directly to the lungs. The nervous system, especially the brain, is also more highly differentiated than in the amphibians, and the bones are more completely ossified. In discussing the frog mention was made of the fact that the skull moves on the first vertebra by two rounded prominences called condyles. In the lizard and other reptiles there is but a single condyle at the base of the skull. A study of Fig. 180 will make clear the relation of the most important organs.

Development. The female pine lizard lays her eggs in the ground, a short distance below the surface; ten or fifteen eggs are deposited in each lot. The eggs are elongated, from 14 to 18 mm. (a little over $\frac{1}{2}$ in.) in length, and are roughened on the surface, which causes dirt to adhere to them. They increase in size as the embryo develops, finally hatching in about two months. The young resemble the adult quite closely in everything but size. They are able to take care of themselves from the first.

The Allies of the Pine Lizard: Reptilia

Definition of Reptilia. The pine lizard will serve as an example of the class Reptil′ia (Lat. *repere,* "creep"), which includes also snakes, turtles, tortoises, alligators, crocodiles, and many forms, the dinosaurs, for example, of which there are no living examples. Reptiles are cold-blooded vertebrates covered with scales or plates; they breathe by lungs throughout their life. A few reptiles are viviparous, but most of them lay eggs, from which the young hatch in the form of the adult.

Lizards. Most of the Lacertil′ia (Lat. *lacerta*, "lizard") are, like the pine lizard, elongate reptiles with four limbs and movable eyelids. A few families have, however, lost one or both pairs of limbs in connection with their adoption of a burrowing life, and the eyes have disappeared beneath the skin. The covering of scales, so characteristic of reptiles, has also in some cases become much reduced. Legless lizards (Fig. 181) may be distinguished from the snakes, which they

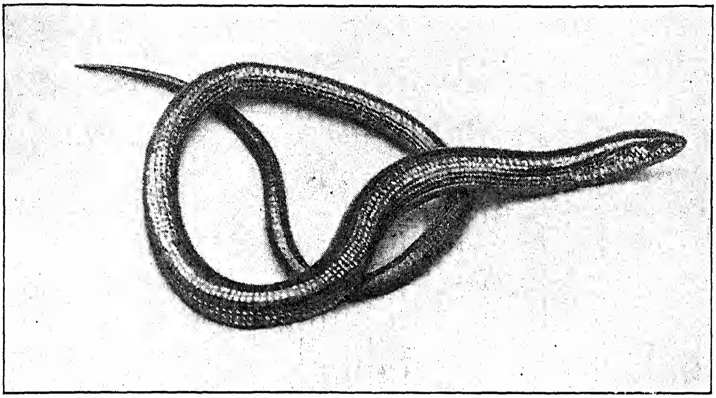


FIG. 181. The glass snake, a legless lizard. (Reduced)

resemble, by the fact that they are incapable of opening the mouth to so great an extent as snakes are. Ear openings on the sides of the head and eyelids which are capable of closing are found in the legless lizards but not in snakes. One of the legless lizards (*Ophisau′rus ventra′lis* (Fig. 181)) is called the glass snake because its body breaks so readily. There are many fables regarding the ability of the glass snake to fly to pieces when struck and later to reassemble its parts and crawl away. The portion of the tail broken off is replaced, but only by the slow process of regeneration and growth.

Many lizards possess the power, when seized suddenly, of snapping off the tail, which may be left in possession of the

captor, while the creature hurries away to safety. Fig. 183 shows a Mexican species of iguana which had thus responded to the efforts of the photographer to take its picture. The same animal before mutilation is shown in Fig. 182. The tail is usually reproduced, at least so far as the flesh and skin are concerned; new vertebræ are not developed. The pattern of the scales on the newer portion of the tail is usually simpler, sometimes apparently reverting to an ancestral type.

FIG. 182. Photograph of a Mexican iguana

The chameleons of the Old World are noted for their color changes, but this power is possessed to a greater or less extent by nearly all lizards. It is accomplished by the shifting of pigment granules in cells in the deeper layers of the skin, toward or away from the colorless outer skin. The movement of the granules, though affected by external conditions, such as color and temperature of surrounding objects, is said to be largely under the control of the animal. On the islands off the Malay coast lizards close to twenty feet long have recently been discovered.

Only one genus of lizard found in North America is poisonous. These are the Gila monsters (*Heloder'ma*) which live in the deserts of our southwestern states.

Snakes. The snakes, which belong to the order Ophid′ia (Gr. *ophis*, "serpent"), are usually very easily distinguished externally by the absence of eyelids and limbs, although rudimentary hind legs are found in a few forms, such as the pythons. Teeth are present in all snakes, and are of two types, — the ordinary teeth, used for seizing food, and the poison fangs, which are perforated, forming a passage for

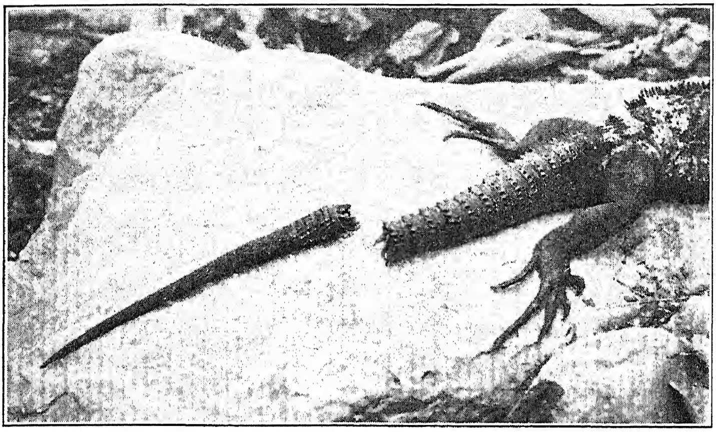


FIG. 183. Photograph of a Mexican iguana with broken tail

the poison secreted in a gland at their base. Both kinds of teeth are shown in the illustration of the skull of the rattlesnake (Fig. 184), which shows also the gland where the poison is secreted (Fig. 184, *9*), and the reserve fangs (Fig. 184, *11*) which replace the first pair when the former are broken or shed. In the nonpoisonous species the number of teeth is much greater than in the rattlesnake.

The tongue of a snake is a long, slender, forked structure, used principally as an organ of touch, not as a fang as many people believe. The lower jaw is joined to the upper jaw in such a way (Fig. 184) as to admit of so much freedom of movement that the snake's mouth can be opened wide

enough to swallow animals greater in diameter than itself. The passage of food into the esophagus is facilitated by an abundant secretion from salivary glands, and escape of the prey is prevented by the sharp, backward-pointing teeth in both jaws. The union of the two sides of the lower jaw in front is so loosely made by a cartilaginous connection that each side of the jaw can be pushed forward independently, thus getting a fresh hold on the food. Some of the larger snakes, as the pythons and boas, kill their prey by constriction; the non-poisonous species may swallow theirs alive; the poisonous species generally kill the animal, unless it be a small one.

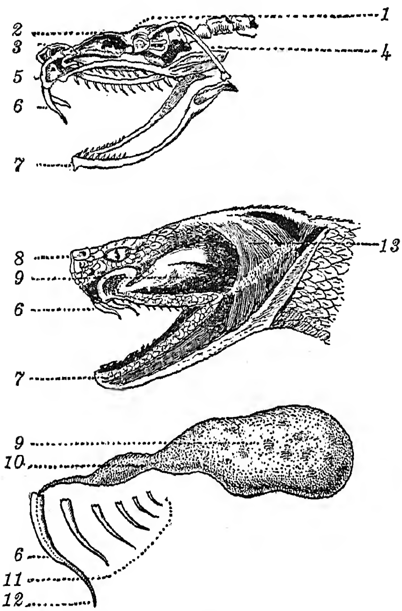


FIG. 184. Skull of rattlesnake, showing poison fangs[1]

1, 2, bones of cranium; *3,* prefrontal bone; *4,* quadrate bone; *5,* maxillary bone; *6,* fang; *7,* bones of lower jaw; *8,* tip of snout; *9,* poison gland; *10,* poison duct; *11,* reserve fangs; *12,* tip of fang; *13,* temporal muscle

In captivity many of the large snakes refuse to eat. In zoological gardens the extremely large pythons are held by several men and a whole animal as large as a rabbit is poked down the throat with a probe.

Snakes crawl by means of muscles attached to the ribs and scales of the under side. These scales have a free posterior edge, which can be inserted into rough places.

[1] From Baskett's *Story of the Amphibians and Reptiles.*

There are more than twenty-three hundred species of snakes in the world. Of these, less than $7\frac{1}{2}$ per cent are poisonous. In North America a still smaller percentage are poisonous. Several species of rattlesnakes (Fig. 185), copperheads, water moccasins, and coral snakes are poisonous, but together they cause only a few deaths a year. This is in sharp contrast to conditions in India and some regions of South America. It is estimated that in Brazil alone about nineteen thousand persons are bitten annually by snakes, and of these close to forty-eight hundred die.

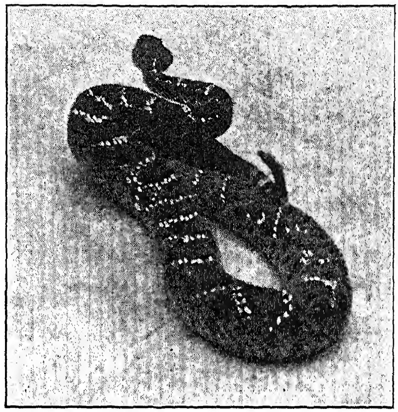


FIG. 185. Photograph of a rattlesnake

The poisons produced by different kinds of snakes act in entirely different manners on the human body. Some destroy the blood corpuscles. Others produce paralysis. The old idea that whisky is an antidote for any kind of snake bite is absolutely false. The most successful treatment is by use of a serum called antivenin. By injecting small doses of the poison of a given kind of snake into horses, their blood produces a serum which counteracts the effects of the poison when injected into a person bitten by the same species of snake.

The poisonous snakes of the United States are the prettily colored coral snake (*Micru'rus ful'vius*, Fig. 186) and the water moccasin (*Agkis'trodon' pisciv'orus*) of the Southern states; the copperhead (*Agkistrodon mok'asen*), found from New England to Wisconsin and southward; and more than a dozen species of rattlesnakes (Fig. 185), found

mostly in the arid regions of the West and Southwest. The use of the peculiar horny appendage, or rattle, at the end of the tail of the rattlesnake has occasioned much discussion. By some it has been thought to be a means of terrifying its prey, so that escape may be rendered impossible; by others it has been regarded as a sex call for its mate, or even as a lure for birds. Many naturalists consider that

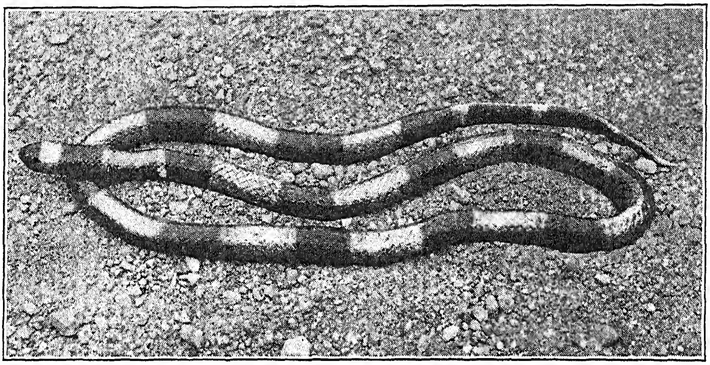


FIG. 186. Coral snake

Photograph by courtesy of the American Museum of Natural History[1]

its function is similar to that of the yellow and black coloration of wasps, or the distinctive red markings of poisonous spiders, — features which serve to mark the possessor as having unusual means of defense. It is thought many conflicts are avoided which might prove disastrous to the rattlesnake, even if the attacker were killed in the contest. As it is, an animal must have some confidence in its powers if it disregards the warning rattle. A diamond-back rattlesnake in captivity in the New York Zoological Park grew a new "button" to the rattle every three months, on each occasion of shedding its skin.

[1] From R. L. Ditmar's *Reptiles of the World*, with the permission of The Macmillan Company.

Of the nonpoisonous snakes of this country the little green snake (*Liopel'tis verna'lis*) is one of the most interesting and beautiful. When kept in confinement it is a harmless and interesting pet. As much cannot be said for our water snakes (*Na'trix*), which are of irritable disposition and disposed to strike when handled. Blacksnakes (*Col'uber*)

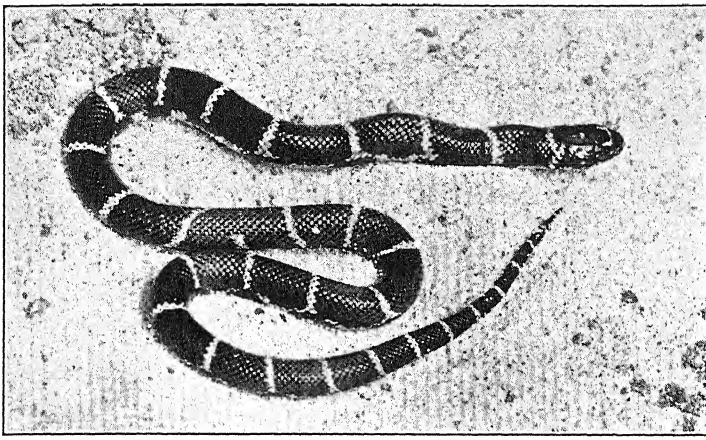


FIG. 187. A king snake

Photograph by courtesy of the American Museum of Natural History[1]

have been kept in captivity and handled freely after they have become accustomed to their new surroundings. Many snakes are not only harmless but are even actually beneficial. The fox snakes (*Ela'phe*) and bull snakes (*Pituo'phis*) feed largely on rats, mice, and other rodents. They are worth protecting around barns and corn cribs. Many of the smaller snakes feed chiefly on insects and worms, while those which live near water commonly add fishes to their diet. Some of the king snakes (*Lampropel'tis*, Fig. 187) are beneficial because they feed on poisonous snakes.

[1] From R. L. Ditmar's *Reptiles of the World*, with the permission of The Macmillan Company.

Some snakes produce eggs with a tough shell, others bring forth living young. Some water snakes (*Natrix*) and garter snakes (*Tham'nophis*) give birth to large families. As many as seventy-five young may be given birth at one time by a female garter snake. The old superstition that snakes swallow their young to protect them is absolutely false. It probably had its origin in the fact that unborn young are sometimes found in the bodies of dead snakes.

Turtles and Tortoises. The turtles and tortoises, Chelo'nia (Gr. *chelone*, "tortoise"), are externally the best protected of all the reptiles, being incased in a shell formed of plates firmly fixed to the vertebræ and ribs. Chelonians have no teeth, but the rim of the jaws is covered with a horny skin. The limbs are sometimes modified into flippers for locomotion in the water, though the land and fresh-water species have digits with claws.

The green turtle (*Chelo'nia my'das*) of the warmer portion of the Atlantic, Indian, and Pacific oceans and the hawkbill (*Eretmoch'elys imbrica'ta*), also widely distributed in warm ocean waters, are economically important, — the first as an article of food, the second as the source of tortoise shell. These turtles lay their eggs in immense numbers on sandy beaches in holes dug for the purpose by the female. As many as two hundred eggs may be laid by a single female. Within about six weeks they hatch, having been incubated by the heat of the sun. These turtles are captured by the natives of different parts of the world, by diving or by nets or harpoons. A peculiar method of capturing them is followed by natives of such widely separated regions as Torres Strait, Madagascar, and Cuba. This method consists in utilizing the services of the sucking fish. This fish is provided with a sucker-like attachment on the top of the head. It is borne from place to place by larger fishes, especially sharks and swordfishes, leaving its host occasionally to

procure food. A string is attached to one of these sucking fishes, which is then liberated in the vicinity of turtles. It soon attaches itself to the under surface of the shell, holding on so tenaciously that the turtle can be drawn gently to the surface. The method was noticed by Columbus or one of

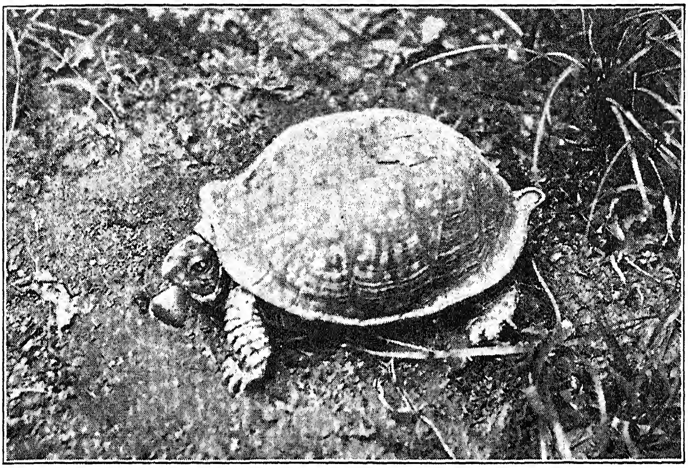


FIG. 188. Photograph of a box tortoise

his companions, and was described in 1671, in the following quotation from Ogilby's *America*:

Somewhat further he [Columbus] saw very strange Fishes, especially of the *Guaican*, not unlike an Eel, but with an extraordinary great Head, over which hangs a skin like a bag. This Fish is the Natives Fisher, for having a Line or handsom Cord fastned about him, so soon as a Turtel, or any other of his Prey, comes above Water, they give him Line; whereupon the *Guaican*, like an Arrow out of a Bowe, shoots toward the other Fish, and then gathering the Mouth of the Bag on his Head like a Purse-net, holds them so fast that he lets not loose till hal'd up out of the Water.

A common species of tortoise in the eastern United States is the box tortoise (*Terrape'ne*, Fig. 188), which lives en-

tirely on land. These tortoises have a very convex upper shell; the lower portion is provided with a transverse hinge, which makes it possible for the animal to bring the two parts of the shell closely together, thus forming a box, within which are concealed head, neck, legs, and tail. A remarkable sex dimorphism occurs; the eyes of the male are red, those of the female, brown. More flattened species, like the painted tortoise (*Chrys'emys*), are better adapted to

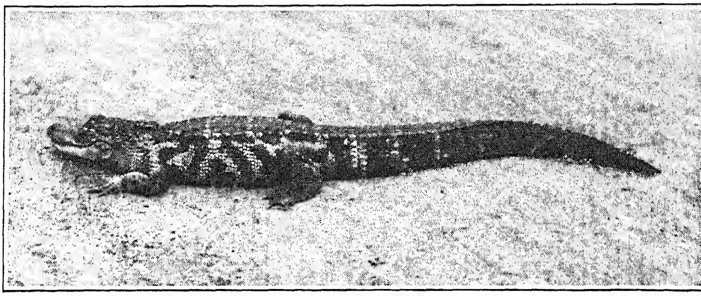


FIG. 189. Photograph of an alligator. (Greatly reduced)

an aquatic existence. The snapping turtles (*Chely'dra*) have extremely powerful jaws. In some localities both the snapper and the soft-shelled turtle (*Am'yda*) are used as food.

Alligators and Crocodiles. The large reptiles known as alligators and crocodiles belong to the Crocodil'ia (Lat. *crocodilus,* "crocodile"). The heart in the crocodilians is highly specialized, having four separate chambers by the complete separation of the ventricle into two chambers. Alligators (Fig. 189) differ from crocodiles in having the canine teeth of the lower jaw fitting into pits in the upper jaw; in the crocodiles they fit into notches in the side of the jaw. A species of each kind is found in Florida, though both have been sought so eagerly for the teeth and skin that they are now found only in the more inaccessible places. Crocodil-

ians are also found in China, Africa, southern Asia, and South America. They frequent the edge of rivers, ponds, and lakes, lying in wait for their prey with only the tip of the snout exposed, or concealed in the vegetation at the edge of the water. They feed at night, and during the day bask in the sun on sand banks or on logs.

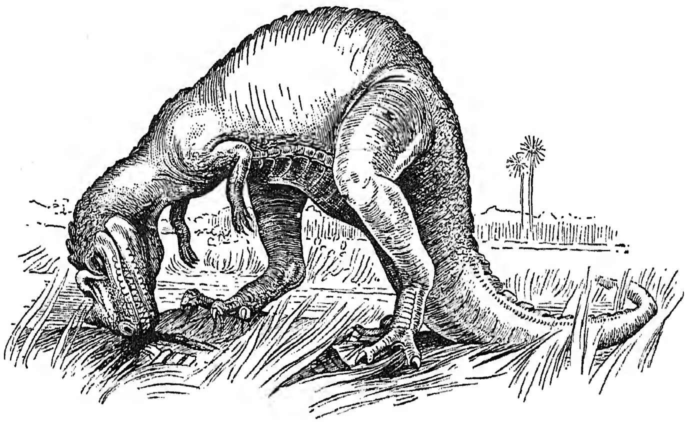


FIG. 190. Reconstruction drawing of the fossil reptile *Ceratosaurus*. (Greatly reduced)

Reptiles of Past Ages. During the Age of Amphibians a great part of the interior of North America was one vast swamp, in which stretches of black water alternated with drier areas covered with the characteristic vegetation of the period, the whole bathed in the heat of a tropical climate. Under conditions similar to these the reptiles first came into existence in the latter part of the Carboniferous Age. They developed in numbers, size, and form, and became in the succeeding period so characteristic a part of the world's fauna that the age is named, from them, the *Age of Reptiles*. This forms the third great division of geological time, called *Mesozoic Time*, or the Era of the Medieval Forms of Life.

Fossil remains of the later part of the Carboniferous Age link the reptiles with the amphibians. Some of the reptiles possessed certain skeletal characteristics of the fur-bearing animals, and they are called theromorphs (beast-formed) on that account.

On land many species of dinosaurs (terrible lizard) were found; some of them were, with the exception of some

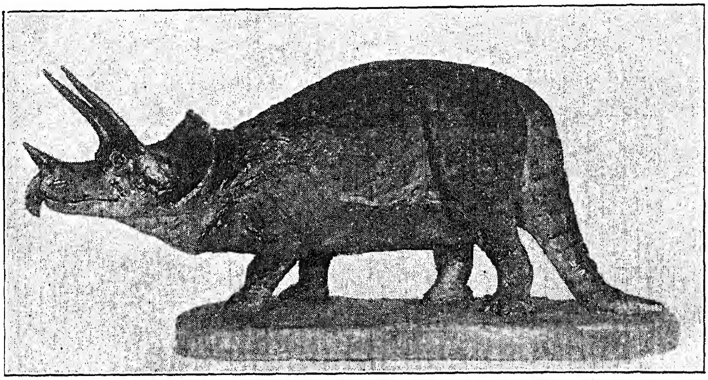


FIG. 191. Photograph of a model of a dinosaur (*Triceratops*). (Greatly reduced)

American Museum of Natural History

whales, the largest animals ever developed on the earth, reaching, in one case, the possible length of eighty or more feet and the height of nearly twenty feet. This animal was so great in bulk that it is considered hardly possible for it to have supported such a vast amount of flesh on land, and it is therefore thought that it was aquatic or semiaquatic in its habits. Some of the dinosaurs, as *Ceratosau'rus* (Fig. 190), were particularly fitted to walk on their hind legs, using the tail as a support. Members of this genus grew to be seventeen feet in height. Hundreds of the footprints of dinosaurs have been found in the sandstone of the Connecticut valley. Fig. 191 shows a well-known dinosaur,

Tricer'atops, with formidable armature. One species reached a length of more than twenty feet, and stood eight feet high. An American scientific expedition into Asia has recently unearthed many interesting fossils. Among the most noteworthy finds was the discovery of dinosaur eggs.

FIG. 192. Restoration drawings of bird-like reptiles, or pterosaurs[1]

Some of the ancient reptiles (the flying lizards, or pterosaurs, Fig. 192) were capable of flight by means of skin stretched between the front and hind limbs and tail. Most of the bones were hollow and the skull was quite bird-like. Reptiles which are apparently related to the alligators and crocodiles, and to the turtles and tortoises, have also been found in the rocks of this period, so that these groups are very ancient. Most of the lizards and snakes belong to a later day.

[1] From Seeley's *Dragons of the Air.*

CHAPTER XXXIV

THE DOMESTIC PIGEON

A hundred wings are dropt as soft as one.
Now ye are lighted — lovely to my sight
The fearful circle of your gentle flight,
Rapid and mute, and drawing homeward soon;
And then the sober chiding of your tone
As there ye sit from your own roof arraigning
My trespass on your haunts, so boldly done,
Sounds like a solemn and a just complaining!

CHARLES TENNYSON TURNER, On Startling Some Pigeons

Habitat and Distribution. The domestic pigeon is known under many varieties, all of which, it is now believed, have been bred by artificial selection from the rock dove (*Colum'ba liv'ia*, Fig. 193), a bird widely distributed throughout the European north-temperate realm. In its wild state the rock dove nests in the crevices of rocks, usually along seacoasts. The different domesticated varieties (Fig. 97) have been still more widely scattered over the earth through man's influence.

External Structure. In the pigeon we can distinguish a *head, neck, trunk,* and *tail.* All over the body the *skin* is closely set with *feathers.* There are two pairs of appendages: the anterior, or *wings,* are used for flight, and the posterior, or *legs,* for support. The wings consist of an *upper arm, forearm,* and *hand,* as in the amphibians and reptiles, though the digits are joined together and reduced in number (Fig. 195). The legs also show divisions similar to the hind legs of amphibians and reptiles; that is, *thigh, lower leg,* and *foot,* the latter being covered with scales and ending in four *toes,* which bear claws resembling those of the lizard.

The mouth is inclosed by a toothless, horny *beak*, above which are situated the two *nostrils*, set in a mass of soft, fleshy skin called the *cere*. The *eyes* are large and have an *upper* and a *lower eyelid* and a *nictitating membrane*. The external openings to the *ears* are a little behind and below the eyes and are surrounded with specially modified feathers. At the base of the tail on the dorsal surface is a *gland* which secretes an oil for keeping the feathers in good condition.

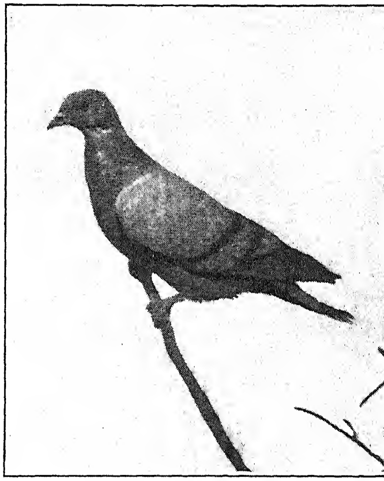


FIG. 193. Photograph of a rock dove. (Reduced)

The feathers are not scattered uniformly over the body, but are arranged in definite tracts separated by areas in which grow only a few hair-like feathers. As an example of a fully developed feather we may choose one of the large *flight feathers* (Fig. 194, *A*) which occur on the wings and tail. It consists of a hollow base, the *quill* (Fig. 194, *A, 1*), from which extends a portion called the *vane*. Through the center of the vane runs the *rachis* (Fig. 194, *A, 2*), which gives off branches called *barbs*. From the barbs run interlocking structures (*barbules*) bearing hooks which serve to bind the vane into one continuous surface. At the junction of quill and rachis on the under surface of the feather a tuft of down, the *aftershaft* (Fig. 194, *A, 3*), is often found. The surface of the body is covered with *contour feathers*, which overlap each other, forming a close covering. Scattered among the contour feathers are *down*

feathers (Fig. 194, *C*), with which the nestling pigeon was covered, and hair-like feathers, or *filoplumes* (Fig. 194, *B*). Down feathers differ from contour feathers in having no barbules, so that the barbs are not held together, but make a fluffy mass. Filoplumes have only a main axis with few barbs.

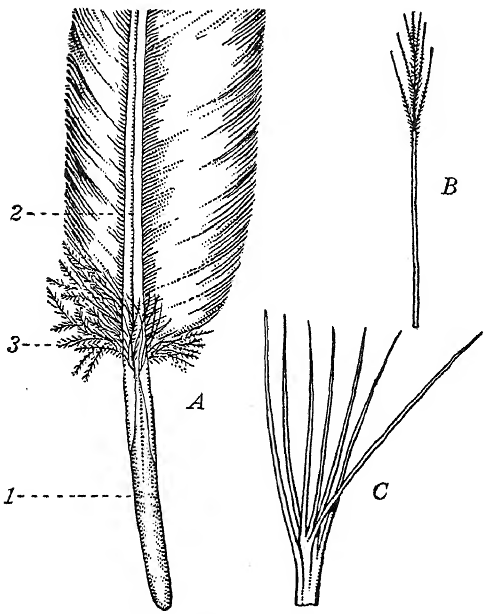


FIG. 194. Feathers of pigeon
A, flight feather; 1, quill; 2, rachis; 3, aftershaft; *B*, filoplume; *C*, down feather

The Digestive System. The *mouth* is without teeth. *Salivary glands* opening into the mouth furnish a fluid which assists in swallowing the food. There is a large *tongue* (Fig. 195), pointed at its anterior end. From the *pharynx* there are openings to the nostrils and to the ears, as in reptiles and amphibians. A short *esophagus* leads to a large *crop,* in which the food, consisting largely of grain, is somewhat softened before passing into the *glandular stomach* behind it. Glands in the lining walls of the stomach pour out a digestive fluid which serves further to soften the food, which then enters the *gizzard,* an organ with a yellow, horny lining surrounded by a thick mass of muscle. The gizzard contains small stones swallowed for the purpose of assisting in grinding the food; this process is accomplished by movements of the

muscular walls. Beyond the gizzard the *small intestine* forms a loop inclosing the *pancreas*, which discharges its secretion into the intestine through three ducts, one of which is shown

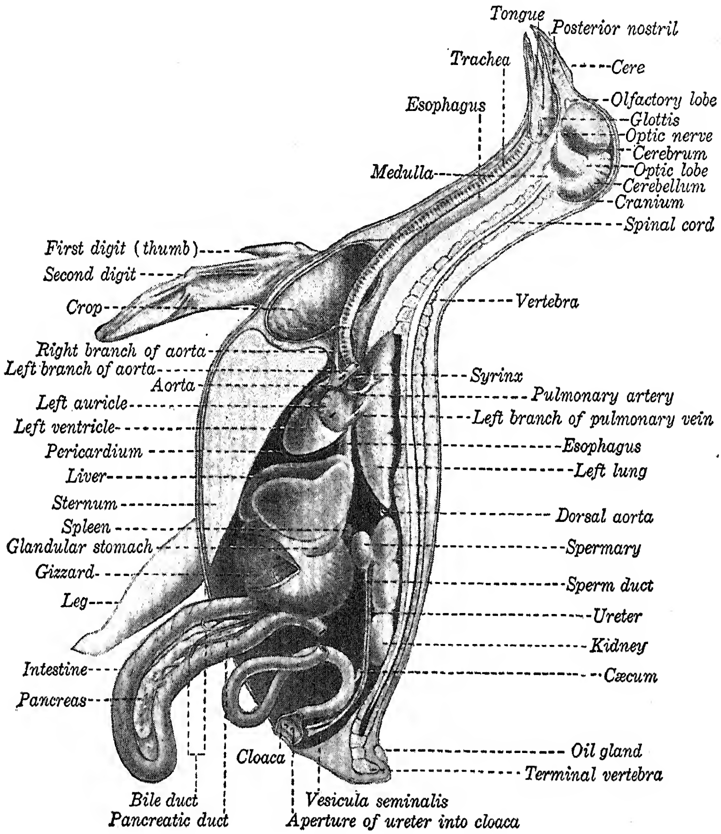


FIG. 195. Dissection of common pigeon. (Reduced)

in Fig. 195. The *liver* is large and opens into the intestine by two *bile ducts*. The posterior end of the intestine (*rectum*) passes without change of diameter into the *cloaca*. The junction between the rectum and cloaca is marked by the

presence of two *cæca*. The *spleen* is bright red, and is attached to the walls of the glandular stomach.

The Circulatory System. The *heart* is a large, four-chambered organ inclosed in the *pericardium* (Fig. 195). It consists of two *auricles* and two *ventricles*, the latter separated by a complete partition. The circulation is double, and the aërated and nonaërated blood come nowhere in contact, except in the capillaries. The blood is sent to the lungs from the right ventricle, through the *pulmonary artery*. Freed of its carbon dioxide, the blood returns through the *pulmonary vein* to the left auricle, whence it passes to the left ventricle and thence into the *aorta*, which distributes it to all parts of the body. The blood from the body returns to the right auricle, whence it enters the right ventricle, completing its circuit. Lymph circulates through the body of the pigeon in vessels of the *lymphatic system*.

The Respiratory System. The organs of respiration are the *larynx*, which opens out to the pharynx by a slit-like *glottis*; the *trachea*; the *bronchial tubes*, which ramify through the tissue of the lungs; and the *lungs* themselves. The trachea is kept open by rings of cartilage in its wall. At the junction of the bronchial tubes and trachea is a slight enlargement, forming the *syrinx*, the organ of voice. The well-known sounds are produced by the vibration of a fold of membrane at this place. Many of the bones are hollow, and there is a system of air sacs scattered through the body and communicating with the bronchial tubes. By these means the air available for respiration is greatly increased and the weight of the body is lessened. Breathing is accomplished by movements of the muscles of the thoracic region, by which air is driven almost completely out of the lungs at each expiration. The aëration of the blood is complete, and a practically constant high temperature, 37° C. (100° F.), is maintained. The pigeon is therefore said to be warm-blooded.

The Excretory System. The *kidneys* (Fig. 195) are dark, three-lobed organs fitting closely into cavities beneath the backbone. The *ureters* open into the cloaca.

The Skeletal System. The *skull* (Fig. 196) is large, with a comparatively large, rounded *cranium.* The articulation of the cranium with the first vertebra is made by a single *condyle,* as in the reptiles. The vertebræ of the neck, or *cervical* region, are free; those of the *thoracic* region, *pelvic* region, and *caudal* region are more or less united. There are several pairs of *ribs.* The caudal vertebræ are terminated by a peculiar bone called, from its shape, the *plowshare* bone. The *shoulder girdle* is composed of a pair of narrow *scapulas,* to which are attached two *coracoids,* connecting the scapulas and the sternum, and a V-shaped bone, the wishbone, formed from the union of the two *clavicles.* A greatly enlarged *sternum* with a prominent ridge, or keel (Fig. 196), serves as a surface for attachment of the muscles of flight. The *hip girdle* is united to the vertebræ of the pelvic region. A study of Fig. 196 and comparison with the skeleton of the frog will make clear in what respects the appendages are different.

The Nervous and Muscular Systems. The *brain* is larger in the pigeon, in proportion to the size of the animal, than in the amphibians and reptiles. The *cerebrum* (Fig. 195) and the *cerebellum* are especially large. One of the principal functions of the cerebellum is to control the muscles which bring about the balancing of the body. It is apparent that this is of greater importance in the birds and fishes than in the broader-bodied amphibians and reptiles. The *optic lobes,* pressed to one side by the large cerebrum, are also well marked, in correlation with the unusually large eyes and the dependence of the pigeon on the sense of sight. The *olfactory lobes* are relatively small, and the sense of smell is not at all keen. The *medulla* is bent downwards, as in the reptiles.

The muscular system shows many adaptations to the aërial life of the pigeon. The great mass of muscle by which the downward stroke of the wings is accomplished occupies almost all the space on the prominent, keeled breastbone. Its position, low down on the body, makes overturning in

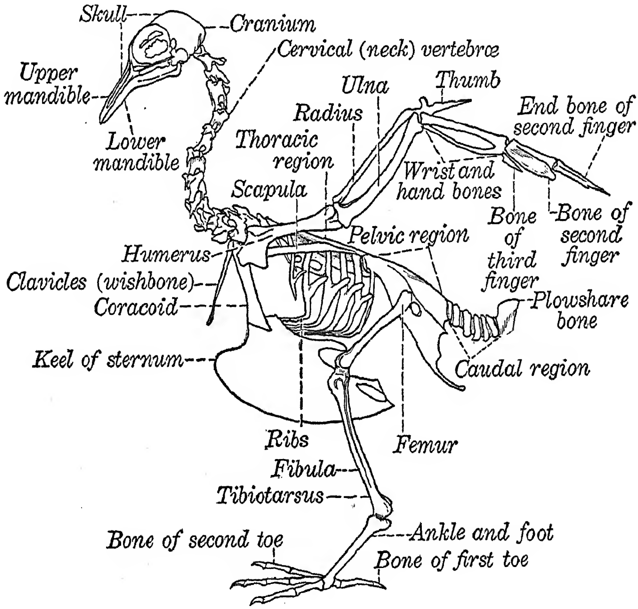


FIG. 196. Skeleton of pigeon. (Reduced)

the air almost an impossibility. The muscle which raises the wing is also situated beneath the breastbone, and is inserted on the dorsal surface of the humerus by a tendon which passes through an opening at the shoulder. The tendon thus acts as a pulley in raising the wing. The muscles which bend the toes in perching are so arranged that the mere weight of the bird keeps them contracted, so that even when the pigeon is asleep the toes firmly grasp the perch.

The Reproductive System. The *spermaries* (Fig. 195) are oval bodies attached to the kidneys. The *ovary* of the right side is not developed, but the left ovary is a large organ situated near the kidneys.

Development. Unlike most of our domestic animals, pigeons choose their mates for life. After fertilization the ova, or "yolks," pass down the oviduct and are covered with secretions from glands in different regions, first with the white, or albumen, then with a thin membrane, and lastly with a white, limy shell. The eggs are laid in a roughly made nest, and are incubated by both parents in turn for about two weeks, when they hatch. The young bird breaks through the shell by means of a hard structure on the tip of its beak, and makes its appearance covered with a fine down. It is interesting to note in this connection that Darwin says that some of the short-beaked tumbler pigeons, which have been developed by artificial selection, have beaks so short that they are unable to get out of the shell alone, and require therefore to have the help of the pigeon-fanciers. For a few days after hatching, the young bird is fed by both parents with a milky secretion afforded by the crop and called "pigeon's milk."

At first the young are deaf and the eyes are closed, but both sight and hearing are acquired within a few days. The young birds rapidly acquire the power to make coördinated, or connected, muscular movements, and in a few days the voice develops. The independent life of the pigeon, in some cases, begins about the thirty-fourth day after hatching.

Relation to Environment. The form of the pigeon is well adapted to cleaving the air, and the feathers form a light waterproof covering which serves to retain the body heat in the rapid flights in the cold atmosphere. "It is worthy of notice," say Parker and Haswell, "that birds agree with insects, the only other typically aërial class, in having the

inspired air distributed all over the body, so that the aëration of the blood is not confined to the limited area of an ordinary respiratory organ." Other important structural peculiarities are the light, toothless beak and the small number of digits in the anterior extremities. Still other characters have been referred to in the discussion of the internal anatomy.

The many varieties of the domestic pigeon afforded Darwin much material for his book *The Variation of Animals and Plants under Domestication*. From this study he obtained many of the conclusions which led to the statement of the principle of natural selection. These domestic varieties differ among themselves in appearance far more than many species in nature. Some well-known varieties are the pouters, fantails, tumblers, and carriers. The pouters are large birds with elongate body and legs, and often with inflated crop and esophagus. The fantails are known by the extraordinary development of tail feathers. The tumblers have the remarkable habit of turning somersaults backward in the air from a considerable height nearly to the ground.

The carriers have the "homing faculty" developed to such an extent that they are useful as messengers. Though shut within a basket and removed long distances from their home, they have been able to find their way back. Carriers have been used by man for many centuries. During the World War homing pigeons were much used at the front when other communication was entirely cut off. In one instance a pigeon carried and delivered a message a distance of almost twenty-five miles in just twenty-five minutes, although one leg had been shot off and the breast injured by a machine gun.

CHAPTER XXXV

THE ALLIES OF THE PIGEON: AVES

Robins and mocking-birds that all day long
Athwart straight sunshine weave cross-threads of song.

SIDNEY LANIER

Definition of Aves (Lat. *avis*, "bird"). The pigeon is a representative of the class A′ves. Birds are warm-blooded vertebrates adapted as a class to an aërial existence. They are covered with feathers, which are, in their origin, modified scales. Birds breathe by lungs. The young are always hatched from eggs in a form closely resembling the parent. There is remarkable uniformity of structure in the class, making classification extremely difficult.

The following groups, which are some of the most important of the many divisions into which birds have been divided, are not all entitled to rank as separate orders, though often treated as orders.

The Ostrich and Allies. The group Struthio′nes (Gr. *struthion*, "ostrich") contains the ostrich of Africa, the rheas, or South American ostriches, and the emus and cassowaries of Australia, New Guinea, and adjacent islands. They are all large birds with rudimentary wings, and with only two or three toes on each foot. They have no ridge, or keel, on the sternum, a structure which in most birds serves as an attachment for the muscles of flight; hence the struthious birds cannot fly, though there is evidence that they have descended from ancestors that had functional wings. The legs are large, and the birds run with great speed. Most of them live in open desert places, though cassowaries inhabit

forest regions. The eggs are laid in a deep depression in the sand, or in a rough nest in the case of the cassowary. The ostrich is the best known of the group, largely on account of the beautiful wing and tail plumes, which have been used for ornaments from very early times. Ostriches are now raised for the sake of the plumes on "farms" in California and South Africa.

Diving Birds. The group Pygop'odes (Gr. *pyge*, "rump"; *pous* (*pod-*), "foot") includes various species of water birds with webbed or lobed toes (Fig. 197). Their scientific name refers to the fact that the legs are placed very far back, so that when standing, an erect position is assumed. The tail is very short. The beak is sharp and pointed and fitted for capturing fishes, which constitute a large part of their food. They are expert divers and can swim under water with only the tip of the bill exposed. The nest is generally nothing more than a floating mass of decaying vegetation, attached perhaps to some reeds in shallow water. Our northern lakes and ponds are often visited by the loon, a characteristic diving bird.

Gulls and Terns. The group Longipen'nes (Lat. *longus*, "long"; *penna*, "feather") includes long-winged water birds with sharply pointed or hooked beaks. The colors are usually gray above and lighter below. The three front toes are connected by a web (Fig. 197). These birds are strong and graceful fliers, and spend much of their time on the wing. All the members of the group are gregarious, occupying nesting sites on sandy beaches, in marshes, or on rocky shores. They obtain the greater part of their food from the ocean and lakes, and are useful as scavengers. Terns (Fig. 198) may be distinguished from gulls by their usually deeply forked tail and straight bill. Gulls are generally pelagic, and they often follow ships for the sake of the refuse thrown overboard; terns frequent the shores of

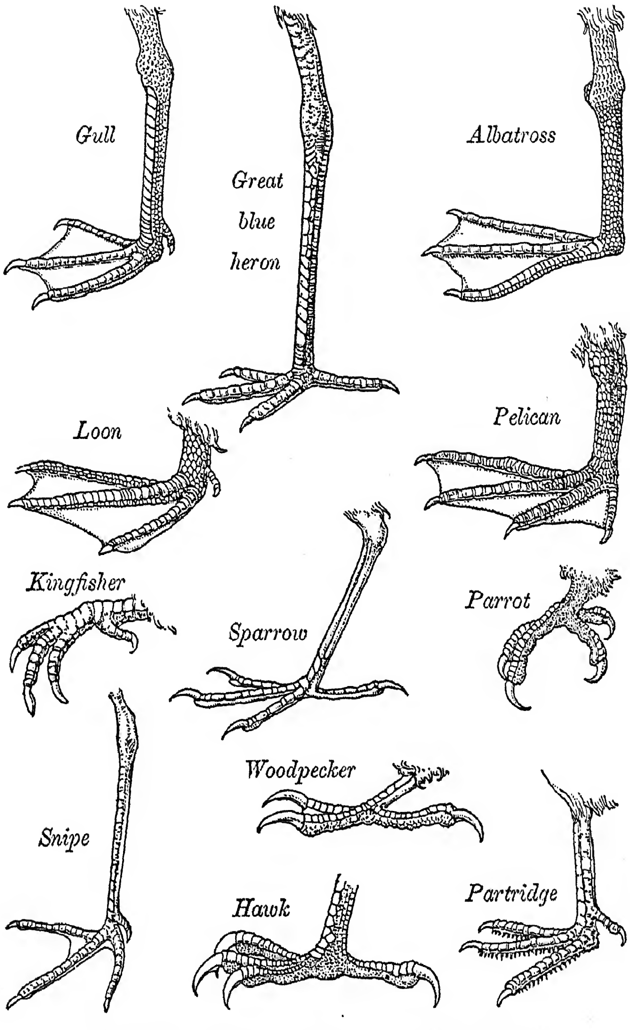


FIG. 197. Specialization in the legs of birds

Although the legs of all birds are constructed on the same general plan, there are many distinctive features that correspond to the different habits of life. There are the webbed toes of water birds — gull, loon, albatross, pelican; the long legs of wading birds — heron; the sharp claws of birds of the predatory habit — hawk. Contrast the climbing foot of the woodpecker with the perching foot ot the parrot and the ground foot of the sparrow or partridge

both fresh and salt water. Owing to the forked tail and graceful flight, the terns are often called sea swallows.

Petrels and Allies. The petrels and their allies are strong-winged pelagic birds, many of which externally resemble the gulls and terns. They may be distinguished from other water birds by the nostrils, which are inclosed in tubes lying

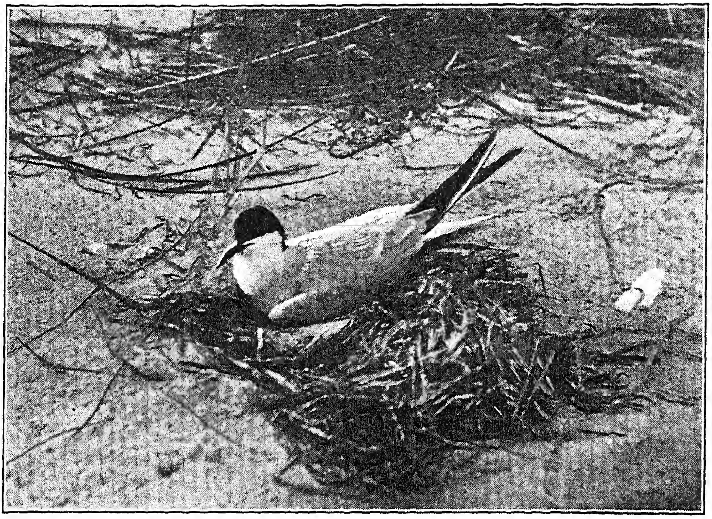


FIG. 198. Photograph of a tern on its nest

on the dorsal or lateral surface of the upper mandible; hence their scientific name, Tubina'res (Lat. *tubus*, "tube"; *naris*, "nostril"). The beak is usually strongly and sharply hooked. The food consists of fishes and other small animals which live near the surface of the ocean. The birds often follow ships, like the gulls, to pick up refuse. They occupy various nesting sites along shores. The wandering albatross (*Dio-mede'a ex'ulans,* Fig. 197) of southern oceans is the best-known species. It is the largest of sea birds, measuring over twelve feet between the tips of the wings. One of the

traditions among sailors concerning the albatross is referred to in Coleridge's *Ancient Mariner*. Other members of the group, called stormy petrels and Mother Carey's chickens, are also regarded by many sailors with superstitious dread.

Pelicans and Allies. The members of the group Steganop′-odes (Gr. *steganos*, "covered"; *pous* (*pod-*), "foot") differ

FIG. 199. Colony of brown pelicans and young on nesting site

The female near the center is protecting the young from the sun. (Photograph by Dr. Alvin R. Cahn)

from all other web-footed birds in that all four toes are connected by a web (Fig. 197). They are aquatic and feed mainly on fishes. To this group belong the pelicans (Fig. 199), remarkable for the pouch beneath the bill, which is used as a scoop to capture food or as a storage reservoir. There are about a dozen species of pelicans distributed over the world, of which two species, the brown and the white pelican, are found in the United States. White pelicans have the habit of surrounding schools of small fishes

and driving them with loud beatings of wings into shallower water, where they can be scooped up in the great pouch and devoured at leisure.

Ducks, Geese, and Swans. The group An′seres (Lat. *anser*, "goose") is made up of water birds which have the three front toes webbed and the tail comparatively well developed. The ducks, geese, and swans are included here. The bill is usually flattened and is furnished with transverse tooth-like ridges on both upper and lower mandibles. In the species which frequent rivers and ponds, feeding largely on vegetable food or on small mollusks, crustaceans, and larvæ of insects, these ridges act as a strainer through which the water runs off when the bill is closed, leaving the food behind; in the harbor species and sea-haunting, fish-eating species the ridges are useful in holding the slippery food. The nest is usually placed on the ground near the water.

Wild geese have long excited interest on account of their peculiar manner of migrating in a flock arranged in a long, V-shaped group, keeping up the continual, sonorous "honk, honk." Among the geese and swans the sexes are usually alike, but in many of the ducks the male is specially ornamented with brilliantly colored plumage. Well-known species of ducks are the canvasback duck, dear to the epicure; and the mallard, the ancestor of the common domestic duck.

Herons, Storks, and Allies. The birds of the group Herodio′nes (Gr. *erodios*, "heron"), often spoken of as wading birds, are long-legged species, with four toes placed on about the same level, and slightly or not at all webbed (Fig. 197). The bill and neck are long and slender. Crests and decorative plumes often ornament the head and neck. Herons haunt the edge of ponds, lakes, and rivers, where they feed on fishes and frogs, which they capture with their long, sharp beaks. They nest in great colonies, usually in trees. The nests are clumsy affairs made of sticks in an untidy mass.

One of our largest species is the great blue heron, which stands nearly five feet high. Several herons, called egrets (Fig. 200), which have the misfortune to grow beautiful dorsal plumes, or "aigrets," at the breeding season, have been practically exterminated by man for the sake of their plumes for women's hats. Fortunately, federal laws now

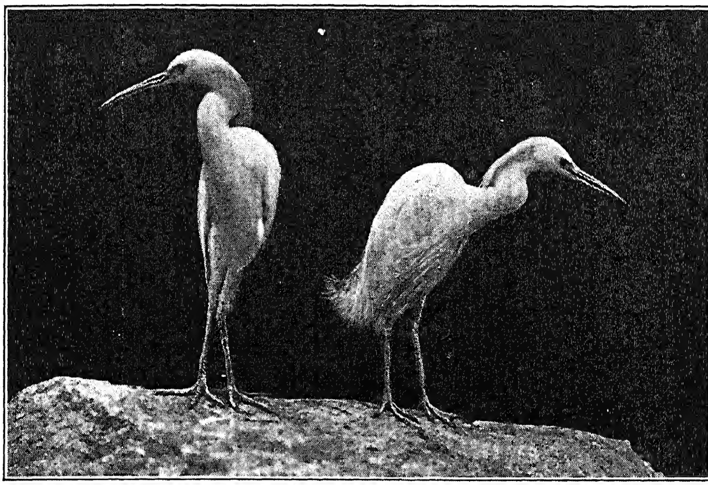


FIG. 200. Photograph of egrets

prohibit the slaughter of these birds and the sale of their feathers. Egrets were formerly common in Florida and along the Gulf coast. Storks are natives of the Old World, frequenting wooded regions or open country. The white stork has been tamed in some countries, where it frequently occupies nesting sites on houses.

Cranes and Allies. Though superficially like the herons, in that they have a long bill, neck, and legs, the cranes and their allies may nevertheless be distinguished from the herons by the elevation of the hind toe above the level of the others. The cranes are scattered widely over the globe, though we

have but three species in North America. They frequent marshes and open plains (their scientific name, Paludic′olæ, means "marsh inhabitants"), and feed on both vegetable and animal food, the latter consisting largely of small reptiles and amphibians.

Erect and tall, they may be seen striding swiftly along with head thrown back, or strutting around their mates; while in spring they often stand in rows and proceed to stalk about in single file, or dance to meet one another with nodding heads, necks advanced, and wings widely outspread. Thereafter they bow toward the ground, jump in the air, and perform graceful antics of all descriptions. The chosen spot for these dances is commonly near water. The male courts his spouse in somewhat similar fashion, and twigs or feathers are often tossed in the air in sport, to be caught again ere they touch the ground.[1]

Snipes, Sandpipers, Plovers, and Allies. The well-known shore birds, included in the group Limic′olæ, usually have long, slender legs, with the hind toe, when present, elevated above the others (Fig. 197). The scientific name refers to their habitat (Lat. *limus*, "mud"; *colere*, "dwell"). The bill is usually long and slender and more or less soft, especially at the tip. With their bills these birds probe the mud and sand of pond and river margins and the seacoast for their food, which consists of small crustaceans, worms, and mollusks. The plumage is usually brown or gray, with some white intermixed. During the breeding season many species give utterance to more or less musical cries. At other seasons a number of species have shrill call notes or whistles. The eggs are usually laid on the sand in a hollow scraped for the purpose. They are very often protectively colored. Like the domestic fowl, the young are able to take care of themselves from the very first. Their nestling plumage is also protectively colored.

[1] *Cambridge Natural History*, Vol. IX.

One of the best known is the woodcock, which frequents low, moist, wooded regions. The tip of the upper mandible can be moved upward, so that it is of use in feeling for and seizing worms in the ground. The Wilson's snipe of fresh-water meadows and swamps, and the upland plover of higher and drier pastures, are other familiar species of shore birds.

Grouse, Quail, Turkeys, Pheasants, and Allies. The gallinaceous birds, Galli′næ (Lat. *gallina*, "hen"), commonly known as scratching birds, have a stout, convex beak with which they pick up seeds of plants, which form a large part of their food. The wings are short and rounded, and the short, stout legs have strong toes adapted to scratching (Fig. 197). Nearly all species are terrestrial in habit. Here are included the larger part of the game birds of the world. By far the best known of the group is our domestic fowl, of many races, all of which are descended from the jungle fowl (*Gal′lus*, Figs. 201, 202) of India, Sumatra, Celebes, and the Philippines.

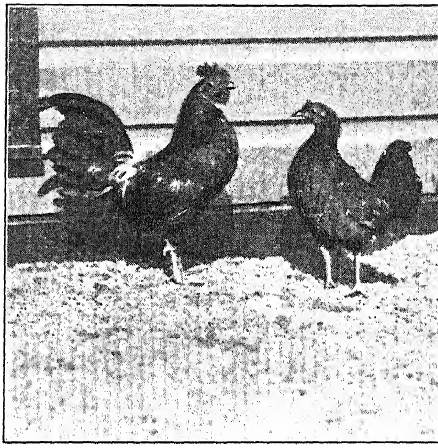


FIG. 201. Photograph of male and female jungle fowl

The best known of the grouse in the eastern United States is the ruffed grouse (*Bona′sa umbel′lus*), usually, but wrongly, called "partridge" in New England. It is about the size of the domestic fowl, and has pronounced black ruffs on the sides of the neck. The male produces a loud drumming sound by beating the air rapidly with the wings.

The sound is a call to the female, though it is indulged in occasionally at other seasons than in the spring. The quail-like bobwhite (*Coli'nus virginia'nus*) is also, but erroneously, called "partridge" in the Southern states. It is a smaller bird than the ruffed grouse, reddish brown in color, and without the ruff about the neck. Neither of these birds should be called "partridge," since that name is already in use for Eurasian species of gallinaceous birds. The same statement is true of the term "quail," which is often applied to our bobwhite. The pheasants are magnificently colored birds, native to southeastern Asia and adjacent islands. The Hungarian partridge and the ring-necked pheasants have been introduced in various regions in the interests of the sportsman.

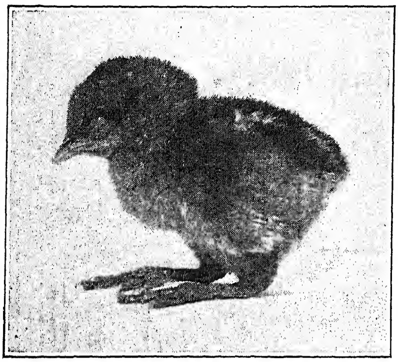


FIG. 202. Young of jungle fowl

Pigeons and Doves. The Colum'bæ (Lat. *columba,* "dove") are closely related to the gallinaceous birds, but the nostrils open into a fleshy cere. The domestic pigeons belong to this group. We have in the eastern United States but one species of wild dove, the mourning, or turtle, dove. The passenger pigeon was formerly present in immense numbers in the wooded regions of the eastern United States. In the early years of the eighteenth century flocks were seen which stretched far across the sky, and which required hours to pass a given point. Owing to the increased demand for both young and adults as food they were slaughtered indiscriminately and have since, to our disgrace as a civilized nation, been entirely exterminated.

Hawks, Eagles, Vultures, and Allies. The Rapto′res (Lat. *raptor,* "robber") are generally spoken of as birds of prey, though the term is equally applicable to some members of other groups, the gulls among the long-winged swimmers, for example. The beak is stout, strong, and sharply hooked (Fig. 203); the toes, arranged three in front and one behind, are provided with strong, sharp, curved claws (Fig. 197) with which to seize their living prey, except in the vultures, which feed on carrion. All the Raptores possess great powers of flight. The female is larger than the male. The nests are generally bulky and are composed of sticks and placed in tall trees or on rocky cliffs.

FIG. 203. Head of golden eagle

The red-shouldered and the red-tailed hawks are generally termed "hen hawks," or "chicken hawks," by farmers. Though they occasionally levy tribute on the chicken yard, their propensities in this direction are not so marked as is the case with some of the other hawks, which do not sail so conspicuously in the air. Except in some localities, hawks undoubtedly do more good than harm by destroying large numbers of mice and other small mammals. The vultures are, generally speaking, scavengers, though they may attack weak and disabled animals. The black vulture and the turkey buzzard are invaluable as scavengers in the Southern states. They have been protected for this reason, and have become very tame in many places.

The owls (Fig. 204) are birds with large eyes and soft, fluffy plumage. They feed almost exclusively on mice and other rodents, though some species are guilty of eating song birds. The great horned owl is even convicted of stealing poultry. The screech owl and most of the other species are not only harmless but render real service in keeping down the population of rats and mice. While feeding they usually swallow their prey entire. After the food is digested the hair and bones are formed into compact masses and ejected from the mouth. Owl roosts are frequently located by the presence of these hard pellets on the ground beneath the trees.

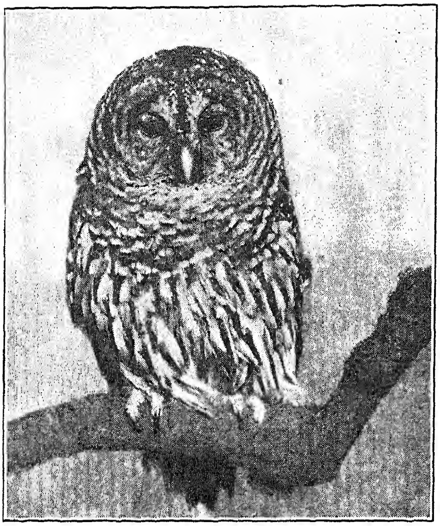


FIG. 204. Photograph of a barred owl

Parrots and Cockatoos. The Psit′taci (Gr. *psittakos*, "parrot") are generally birds of gaudy colors, with a very stout, strongly hooked beak, which is used for climbing, as well as for crushing seeds. They have four toes, arranged two in front and two behind, with strong, curved claws (Fig. 197). Most species inhabit forests; they are all good climbers. A great many species can learn to talk, but the red-tailed gray parrot of Africa is considered the best talker. The cockatoos are often ornamented with crest feathers of various colors. They are restricted to Australia, Tasmania, and the Philippines. A New Zealand parrot, the kea (*Nes′tor*

nota'bilis), has of late years become carnivorous in its habits, alighting on the backs of live sheep and digging deep into the flesh for the fat surrounding the kidneys. "The propensity is said to have originated from the bird's pecking at sheepskins hanging outside country stations." We have only one member of the group in the United States, the Carolina paroquet, and that has been almost exterminated.

Woodpeckers. The group Pi'ci (Lat. *picus*, "woodpecker") forms a well-marked assemblage of climbing birds, with two toes in front and two behind (except in the three-toed woodpeckers, Fig. 197).

Woodpeckers have a strong, straight bill, with which they dig into wood for insects, and a long, barbed tongue, spear-pointed at the end, which enables them to draw their food from beneath the bark of trees. The tail feathers are usually stiff and pointed, and form a support to rest on while the bird is engaged in feeding. The usual coloration in the group is black and white, but red often appears on the head. The nests are made in holes in trees, and the eggs are white in color. By far the greater number of the woodpeckers are beneficial to the farmer, but the yellow-bellied woodpecker, or sapsucker (*Sphyrapi'cus va'rius*, Fig. 205), girdles trees with numerous small holes to get at the sap beneath the bark. The flickers (*Colap'tes*) have lost some of the habits of the family, and have descended to picking up part of their food on the ground of fields and pastures. For much of the year their food consists very largely of ants.

Perching, or Singing, Birds. The passerine type (Lat. *passer*, "sparrow") is exemplified in more than half the birds of the world. The characteristics which serve to distinguish the Pas'seres, or perching birds, from other groups are the presence of four toes without webs, placed at the same level, three in front and one behind (Fig. 197, sparrow). The perchers are birds of small or medium size. Among them

are included all our well-known songsters. The nesting habits are various, but a great number build complicated and often beautiful nests (Fig. 206) in which to rear their

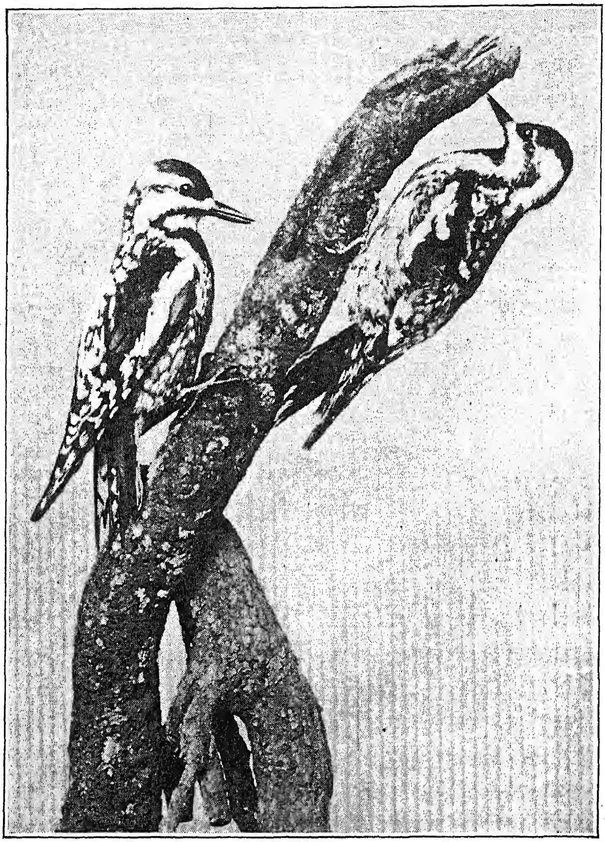


FIG. 205. Photograph of yellow-bellied sapsuckers
American Museum of Natural History

young. The young when hatched are always in a helpless condition, requiring the care of the parent for a time (compare Figs. 207 and 202). The sexes may be alike, or the male

may be specially ornamented. The bright colors of the male are generally believed to be due to sexual selection, and his

FIG. 206. Photograph of nest and eggs of catbird

ability to sing is accounted for in a similar manner. The perching birds are the familiar birds of forest, field, and garden, and are those with which the young student will naturally begin his study in the field. They are so numerous that very few can be referred to here.

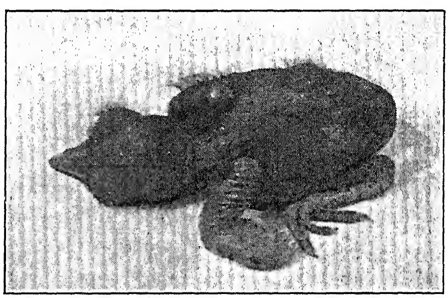


FIG. 207. Recently hatched young of catbird

The flycatchers (Tyran′nidæ Fig. 208) are pert little birds with a slightly hooked bill, provided with bristles at its base. From some convenient perch they watch for insects, which they snap at on the wing, returning to the perch after each flight. The bristles

at the base of the bill serve to entangle insects and make their capture more certain. The brightly colored warblers (Mniotil′tidæ), as Mr. Chapman says, are "at once the delight and the despair of field students." The many species are insect-eaters, getting their food almost exclusively from the leaves or bark of trees, though some capture it on the wing, after the manner of the flycatchers.

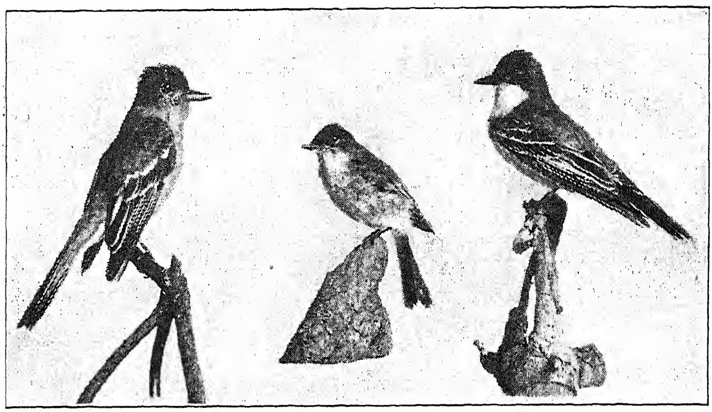


FIG. 208. Flycatchers
American Museum of Natural History

The vireos (Vireon′idæ) are to be found in much the same places as many of the warblers, industriously picking insects from the leaves of trees, or from crevices in the bark. Vireos are small, greenish-colored birds, which build cup-shaped, hanging nests of plant fibers, lined with pine needles and similar material. The white-eyed vireo has the habit of often weaving a piece of newspaper into the structure of its nest; hence it is called "the politician" in some parts of the country. A cast snake's skin is also a favorite object for this purpose.

Our familiar crow and our almost equally familiar blue jay are members of the family Cor′vidæ. The family is

considered by ornithologists to be unusually intelligent, and by some is even considered the highest bird group. Closely allied to the crows and jays are the blackbirds and orioles (Icter′idæ). In this family is the cowbird, which has the habit of laying its eggs in the nests of other birds, which are usually smaller than itself, and of leaving the egg to be hatched by its foster parent. A South American cowbird lays its eggs in the nest of another species of cowbird, which does not possess this parasitic habit fully developed, since the latter sometimes builds its own nest and sometimes lays its eggs in the nests of other birds. The orioles are remarkable for their elaborately interwoven hanging nests, much deeper than the somewhat similar hanging nests of the vireos.

The finches and sparrows (Fringil′lidæ) are the largest family of birds. However varied the members of this group are in form and color, they agree, usually, in the possession of a stout, conical bill, adapted to crushing seeds. The European house sparrow, often called the English sparrow (*Pas′ser domes′ticus*), is well known to dwellers in nearly every town and city in the United States. Introduced from Europe into this country in the neighborhood of Brooklyn, in 1851 and 1852, the house sparrow has since spread so widely that it may now be said that its conquest of the centers of population in our country is almost complete. It has made itself at home in our city streets, and has managed to pick up a living where another bird would starve to death. Most of the sparrows belong to the fields and hedges, where their brownish coloration serves to make them inconspicuous.

Our American robin belongs to the family of thrushes (Tur′didæ). Though not a gifted songster, like some of its near relatives, the robin is dear to all dwellers in the country. With the bluebird and the song sparrow it shares the honor of being spring's harbinger among the birds in eastern North

America. Its habits, song, and call notes offer an interesting subject for study.

Migration of Birds. The phenomena of migration are especially noteworthy among birds, and the birds of a region may be roughly classified in connection with this habit. Those species which remain in a region all the year are spoken of as *permanent residents* of that region. They may be more or less migratory as individuals; that is, the birds seen in the summer may not be the same individuals that appear in the autumn or winter. The great majority of the birds of the northern hemisphere leave in the autumn to pass the winter in the south, returning in great bird waves in the spring. These birds are the *summer residents* of the region. The summer residents of the eastern United States may pass the winter in the Southern states, or they may (like the bobolink) go as far as Brazil (Fig. 209). When the great hordes of the summer residents have passed to the south, other birds come down from the north; these are *winter visitants*. Often a bird loses its way, or is blown out of its regular line of travel to other regions; such birds are *accidental visitants* to those regions.

The great migratory movements of birds are fairly regular year after year, and they are participated in by thousands upon thousands of individuals. When the appropriate time comes each species gathers in large flocks, or the individuals separately move off on their long trip. The larger birds, with special means of defense, as the large hawks and cranes, choose daylight in which to travel. Ducks and geese migrate in flocks, flying either by day or by night. Some of the smaller birds which are also rapid and untiring fliers, like the swallows, also carry on their migrations during the day, but most of the smaller birds migrate at night. A foggy night causes the death of large numbers of birds; over fifteen hundred individuals have been picked up at the foot

of the Statue of Liberty in New York Harbor after a dark night in the migration period. Attracted by the bright light the birds had dashed against the glass in their swift flight. Birds are exposed to other dangers on their

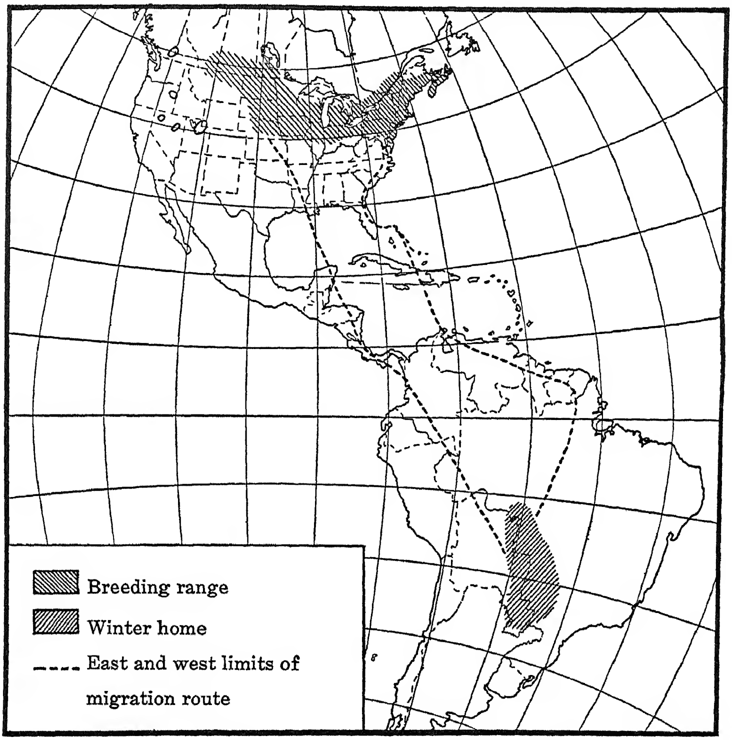


FIG. 209. Map showing migration of the bobolink
Courtesy of the United States Department of Agriculture

migration flight. They are fed upon by other animals, or are blown out to sea, where they fall exhausted into the water.

It is not thoroughly understood how birds find their way over such great stretches of territory. The "fly lines" of some swallows are ten thousand miles long. The golden

plover breeds in arctic America and winters in Patagonia. The bobolink spends the summer in the northern part of the United States and Canada but winters in Brazil. The paths which the bobolinks follow in their two trips a year fall between the two broken lines shown on Fig. 209. By some ornithologists the ability to travel these great distances is ascribed to the possession of a sixth sense, — that of direction. In some cases rivers and coast lines are followed. It has been observed that there are instances in which birds now follow the outlines of old, submerged coast lines.

While members of some species cover great distances in a single day the migration speed is rarely more than fifty miles an hour, and for all our species the average rate of migration is not much more than twenty miles a day, for there are frequent stops of one or more whole days for feeding.

The causes which underlie these great movements cannot yet be stated with certainty. One very careful student of bird migration has observed that in the spring migration the appearance of greatest numbers of individuals and "first arrivals" follows after a day of high temperature and winds from the south when areas of low barometric pressure are moving northward. It has been stated that the return to the north is due to the desire of the birds to regain their old home, or to their desire for seclusion during the breeding season. The origin of the habit has been looked for in the geological history of the world. During the Glacial Epoch a great part of the northern hemisphere was shrouded in a mass of ice, which came down from the north upon a region which was then almost tropical in its climate. With the onward advance of the ice, the birds, like all other forms of life, were driven south, returning whenever the melting of the ice permitted. Geology tells of many periods of alternate progression and regression of the ice sheet, with accompanying changes of climate. It may well be that the

northerly and southerly movements then begun among the birds have been continued till today.

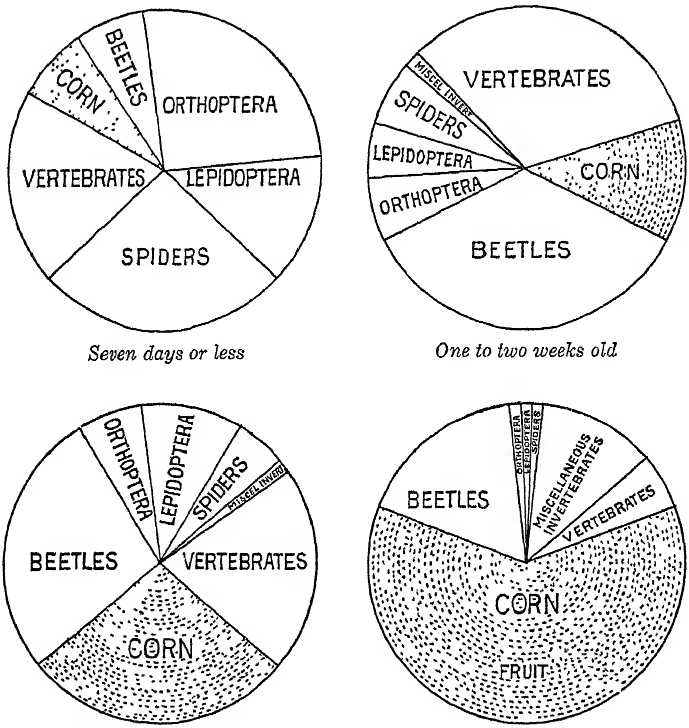
Bird-Banding. In the past few years much valuable information about movement and migration of birds has been obtained by banding. Small metal bands are placed on the feet of young birds before they leave the nest and of old birds captured in traps. These bands bear numbers and instructions to notify the Biological Survey at Washington, D. C., in case the bird is killed or trapped. By this means it has been determined that in many species individuals return year after year to exactly the same nesting site. Migration routes are also studied in this manner.

Economic Importance of Birds. Leaving out of consideration their value to man as a source of food, birds are chiefly important economically in connection with their destruction of insects injurious to vegetation. Of course not all birds are beneficial in this respect; whether they are beneficial or injurious depends largely on the character of their food. What we know of the food of birds has come not only from the observation of the birds in the field but also from the examination of the contents of their stomachs. The Bureau of Biological Survey of the Department of Agriculture has performed a most useful task in collecting, tabulating, and publishing observations from all parts of the country. The diagram (Fig. 210) shows the proportion of different sorts of food in the young and the adult of the common crow.

Some of the conclusions of Dr. Judd, who studied the birds of a Maryland farm for the Biological Survey, are as follows:

> . . . the English sparrow, the sharp-shinned and Cooper hawks, and the great horned owl are, as everywhere, inimical to the farmers' interests and should be killed at every opportunity. The sapsucker punctures orchard trees extensively and should be shot. The study of the crow is unfavorable in results so far as these

particular farms are concerned, partly because of special conditions. Its work in removing carrion and destroying insects is serviceable, but it does so much damage to game, poultry, fruit, and grain that it more than counterbalances the good, and should



Seven days or less — *One to two weeks old* — *Three weeks and older* — *Adult*

FIG. 210. Diagrams showing relative amounts of different kinds of food eaten by crows of different ages[1]

be reduced in numbers. The grackle appears to be purely beneficial to these farms during the breeding-season, and feeds extensively on weed-seed during migration, but at the latter time it is very injurious to grain. The remaining species probably do more good than harm and, except under unusual conditions,

[1] From Judd's *Birds of a Maryland Farm.*

should receive encouragement by the owners of the farms. Certain species, such as flycatchers, swallows, and warblers, prey to some extent upon useful parasitic insects; but on the whole the habits of these insectivorous birds are productive of considerable good to man. Together with the vireos, cuckoos, and woodpeckers (exclusive of the sapsuckers), they are the most valuable conservators of foliage on the farms. The quail, meadow-lark, orchard-oriole, mocking bird, house-wren, grasshopper-sparrow, and chipping sparrow feed on insects of the cultivated fields, particularly during the breeding-season, when the nestlings of practically all species eat enormous numbers of caterpillars and grasshoppers.

Bird Protection. The first steps toward bird protection were taken at the instance of the sportsmen, in whose interest laws were passed prohibiting the destruction of game birds except at stated seasons of the year. These laws were in the interest, too, of the hunter who shot for the market, since they secured for the birds freedom from the molestation of man during the period of bringing up their young, without which protection their extinction would, in many cases, have been only a matter of time. Of late years great interest has been aroused in ornithology, and the value of birds to agriculture or as scavengers has been more generally recognized. People generally have begun to take pleasure in having birds about, for their beauty of form, or color, or movement, and for their song, so that an æsthetic argument has been added to the others. The separate states have shown the effect of this general awakening by the improvement of old laws or the passage of new ones for the protection of the insectivorous song birds and other birds which have not been proved to be directly injurious. As one result of the interest in the study of birds in the schools several states have set apart Bird Day, which is observed after the fashion of Arbor Day, and oftentimes in connection with it. The first Bird Day was observed in Pennsylvania, May 4, 1894.

The greatest single act for the protection of our bird life was a treaty entered into by the Canadian government and the United States in 1916. By the terms of this treaty game birds may not be killed in the spring, which is the breeding season, and the sale of migratory birds is prohibited everywhere in the United States and Canada. This treaty recognizes the fact that migratory birds are not the property of the state where they happen to reside for a few months of the year, and places their protection in the hands of the federal government. Before this treaty became effective water fowl were on the verge of extermination in many parts of the country. Since 1916 there are strong evidences of increasing numbers.

Our national parks and forests in addition to furnishing a playground for citizens of this country are under an administration which furnishes protection not only to game animals but to many kinds of birds as well. In addition to the federal government, the various states and numerous private organizations have set apart regions where birds are given complete protection. These sanctuaries, or refuges, as they are called, now number close to one hundred and are scattered over the entire country. Some of them are small, but a few acres in extent, while others cover several thousands of acres. In many of the larger sanctuaries wardens are constantly on guard to protect the birds from depredations of wild animals and their even greater enemy, man. In some of the private sanctuaries remarkable work has been done. Jack Miner on his Canadian estate feeds thousands of ducks and geese, which he claims are not wild except as we make them so.

Increased interest in our wild life has led to the planting by many persons of fruit-bearing trees and shrubbery to attract the birds. In the winter many find pleasure in keeping feeding stations provided with food to attract the winter residents.

Geographical Distribution of Birds. Because of their strongly developed powers of flight, birds have fewer barriers to their distribution than exist for most other animals. As a result the same species frequently occur over large areas. In the United States, the Rocky Mountains are a distinct barrier to many species of birds. Except where barriers exist, regions offering similar conditions for life may have the same species of birds even though they be widely separated geographically. Thus the entire area east of the Rocky Mountains has practically the same species of bird inhabitants, while west of the Rockies there are many species different from those of the Eastern United States.

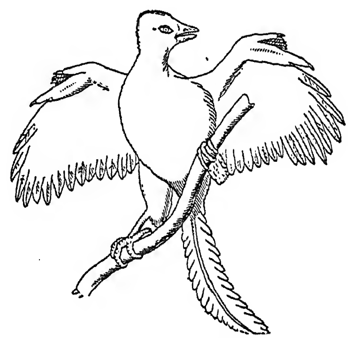


FIG. 211. Reconstruction drawing of the primitive fossil bird, *Archæopteryx*
After Pycraft

When a given species of bird occurs over a wide area, there are often minor differences such as of color or of size which distinguish the individuals of one region from those of another. These differences mark off the varieties within a species, as mentioned on page 108. Thus, though song sparrows occur from one coast to the other, they represent a considerable number of varieties.

Birds of Past Ages. The earliest remains of birds of which we have any knowledge come from the Age of Reptiles. The oldest of these remains is the famous fossil known as *Archæop'teryx* (Fig. 211), two specimens of which have been found in Bavaria. The ancestry of all known birds is therefore to be traced back, at least so far as our knowledge goes, to these two specimens. *Archæopteryx* was a land bird about the size of a crow, probably arboreal in its habits,

though not necessarily a good flier. It had true feathers, but it was very different from the birds of today in that it possessed teeth and a long, lizard-like tail of about twenty vertebræ. These last characteristics are strikingly reptilian, and such considerations point to the fact that the birds developed from the reptiles. As the development was undoubtedly gradual, we should expect to find forms possessing the characters of both groups.

Many remains of birds have been found, especially in the rocks on the eastern slope of the Rocky Mountains, in Kansas and Colorado. These belong to species which lived later in the period. These birds are of at least two different types, differing in the arrangement of the teeth. One group had the teeth set in separate sockets; the other had the teeth in grooves. Some of the birds found in the rocks of this age in New Jersey seem to have been toothless, like birds today. It is interesting to note that even thus early the bird type had become quite well advanced, having lost not only the teeth but also the long tail of earlier forms. The time of this period was great enough to permit the development of species of birds with highly developed wings, as well as others with degenerate wings.

In the next succeeding period, to which we shall refer at the close of a later chapter, the birds were all toothless and related to those of today. There were woodpeckers, parrots, swallows, cranes, and many others.

CHAPTER XXXVI

THE GRAY SQUIRREL

Up the oak-tree, close beside him,
Sprang the squirrel, Adjidaumo,
In and out among the branches,
Coughed and chattered from the oak-tree.
Laughed, and said between his laughing,
"Do not shoot me, Hiawatha."

LONGFELLOW, The Song of Hiawatha

Habitat and Distribution. The gray squirrel (*Sciu'rus carolinen'sis*, Fig. 212) was formerly found all over the wooded region of the eastern United States, and still exists, though in much diminished numbers, wherever its numerous enemies permit. It does not extend farther west than Minnesota and Wisconsin. It lives in those regions where hardwood trees grow, seldom being found in the depths of coniferous forests.

External Structure. The elongate body is covered with a *skin* bearing soft hair, and is clearly divisible into a *head, neck, trunk,* and *tail.* There are two pairs of appendages, the *legs.* In addition to their use in running and in climbing, the fore legs are used in grasping objects and bringing them up to the mouth. The hind legs serve for making the long leaps so characteristic of the squirrel's method of progression in trees. Both pairs of legs show the divisions which we have already noted in the amphibians, reptiles, and birds, and they are provided at the end with digits ending in horny *claws.* The *nostrils* (Fig. 215) are situated at the anterior extremity, just above the mouth. The *eyes* are large, and furnished with an *upper* and a *lower eyelid* and a *nictitating membrane.* About the mouth and eyes are long, sensitive

hairs called *vibrissæ*. At the back of the head are movable flaps of skin (external ears, or *pinnæ*) placed at the opening of the *ears*. The long and bushy tail is useful in a number of ways: it is an ornament; it is useful as a balancing organ in the long leaps from branch to branch; and it serves to keep the squirrel warm in its nest in cold weather.

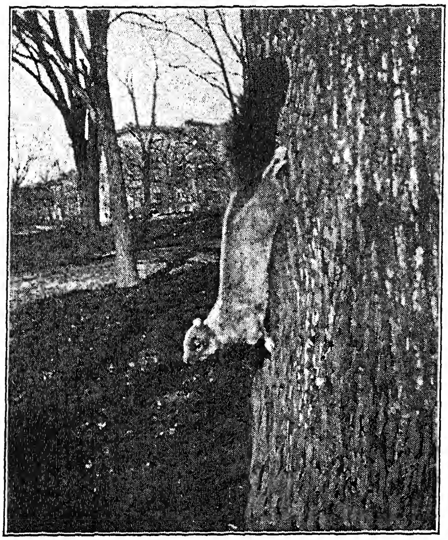


FIG. 212. Photograph of a gray squirrel

The Digestive System. The *mouth* is provided with fleshy *lips*, which assist in seizing and holding food. On the ventral surface of the mouth rests a large, fleshy *tongue* (Fig. 215), with numerous nerve endings of the organ of taste (*papillæ*) scattered over the surface. The front teeth, called *incisors* (Fig. 215), are long, sharp, and chisel-shaped, and are fitted for gnawing; those in the back of the jaw, separated from the incisors by quite a space, are shorter, broader, and flattened on top, and are fitted for grinding (Fig. 213). The incisors are four in number, two in each jaw; the grinding teeth in an adult squirrel may be eighteen in number, — four on either side of the lower jaw and five on either side of the upper jaw. Of the grinding teeth the last three on either side in both jaws are termed *molars*, the others *premolars*. One of the premolars in the upper jaw is very likely to be minute, or even missing, having been shed in early life.

A tooth contains a *pulp cavity* (Fig. 214, *4*), supplied with blood vessels and nerves and surrounded by a mass of firmer tissue, or *dentine* (Fig. 214, *3*), which makes up the bulk of the tooth. The dentine is usually covered, where the tooth projects from the gum, with a very hard, smooth substance called *enamel* (Fig. 214, *1*); below there is a bony substance, the *cement* (Fig. 214, *2*), surrounding the root of the tooth.

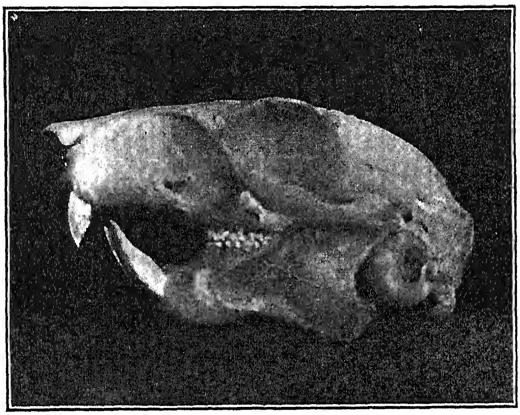


FIG. 213. Skull of a squirrel

In the molar teeth of the squirrel the pulp cavity, which is at first open at the base, as in the case of man (see Fig. 214, *B*), becomes inclosed and develops a root (see Fig. 214, *C*), after which all growth of the tooth stops. In the incisors of the squirrel the pulp cavity persists throughout life, remaining open so that the tooth continues to grow as fast as it is worn away. The enamel is confined to the front surface of the incisors, so that when the tooth is used on hard substances the softer dentine wears away more quickly and the tooth becomes sharper and more like a chisel the more it is used.

In most fur-bearing animals the lower jaw is articulated to the upper by means of transverse *condyles*, but in the

squirrel and its allies the condyles are parallel with the long diameter of the head, thus allowing some backward and forward motion of the lower jaw. The advantages of these special adaptations of the structure of teeth and jaws to the life of a gnawing animal like the squirrel are obvious.

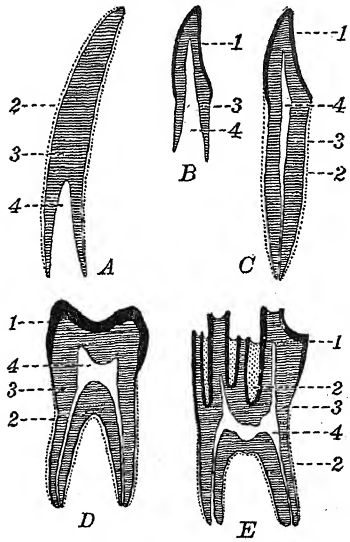


FIG. 214. Sections of teeth

A, incisor, or tusk, of the elephant; *B*, human incisor during development; *C*, human incisor completely formed; *D*, human molar; *E*, molar of ox; *1*, enamel; *2*, cement; *3*, dentine; *4*, pulp cavity[1]

The ducts of four pairs of *salivary glands* open into the mouth. A muscular flap, called the *soft palate*, to distinguish it from the roof of the mouth, or *hard palate*, separates the mouth from the *pharynx* (Fig. 215). Embedded in the soft tissues of the soft palate are the *tonsils*, two small oval bodies, the function of which is unknown. The nostrils open posteriorly into the pharynx. The *Eustachian tubes* from the ears enter the pharynx at the sides.

A short, straight *esophagus* (Fig. 215) leads to the sac-like *stomach*, passing through a muscular partition called the *diaphragm*, which separates the heart and lungs in the thoracic cavity from the organs of the abdominal cavity. In the first fold of the intestine is the *pancreas*, an extended mass of spongy tissue roughly suggesting a bunch of grapes. The *liver* is large and is divided into several lobes. The intestine is very long and much coiled. A clearly marked

[1] From Flower and Lydekker's *Mammals*.

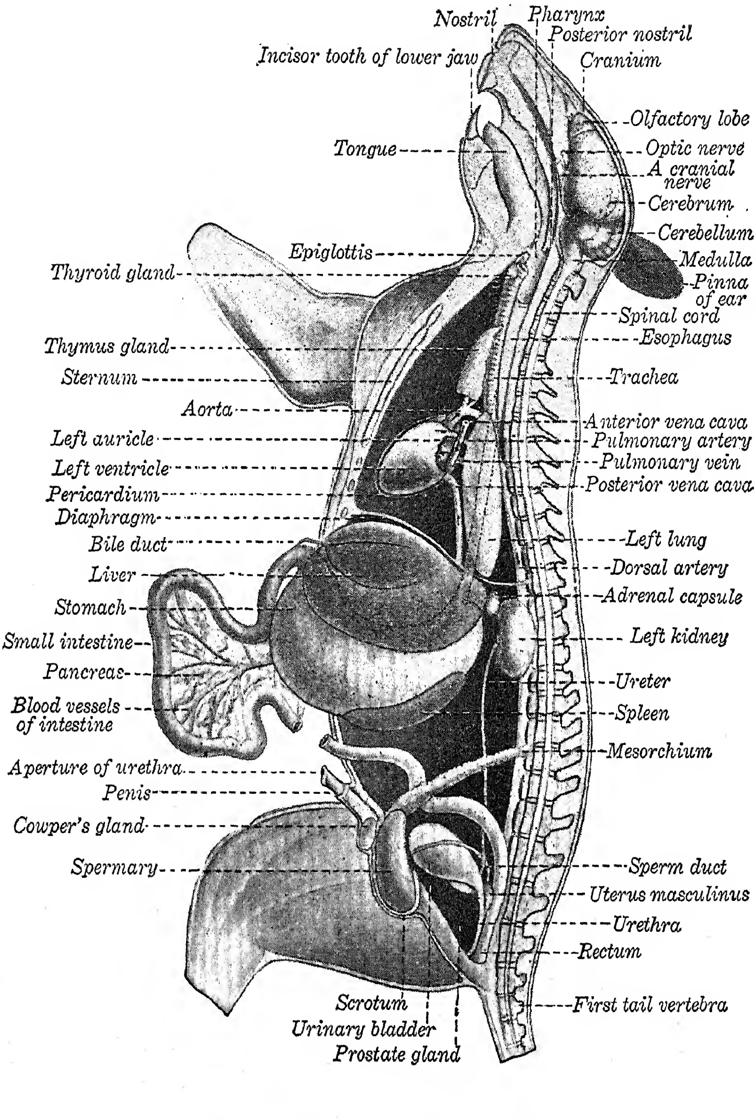


FIG. 215. Dissection of the gray squirrel

anterior portion, the *small intestine,* can be distinguished from the posterior portion, or *rectum.* At the junction of the small intestine and rectum is the *cæcum,* from which projects a closed finger-like *vermiform appendix.*

Ductless Glands. Several glands, called *ductless glands* (owing to the absence of a duct leading from them), are present in vertebrates. With the single exception of the spleen (mentioned in each case in the course of the statements concerning the digestive system) they have not been referred to in our brief discussion of the internal anatomy of the classes of vertebrates, but as they show plainly in the squirrel attention may be called to them at this time. They are, besides the *spleen* (Fig. 215), the *adrenal capsules,* just anterior to the kidneys, the *thymus gland* and the *thyroid gland.* In addition to these, there are other ductless glands of much smaller size. Among these are the *parathyroids,* closely associated with the thyroid, and the *hypophysis* in the ventral part of the brain. Groups of cells in the gonads, called the *interstitial cells,* have nothing to do with the formation of germ cells but regulate the development of the secondary sexual characters. Though their functions are but imperfectly known the ductless glands are coming to be considered among the most important organs of the body. They regulate and control the actions of many other organs.

The Circulatory System. The *heart* is inclosed in a *pericardium* (Fig. 215) and is of the four-chambered type found in the birds. There is a complete double circulation of the blood in the squirrel, as in birds. The lymphatic vessels of the abdomen, called *lacteals,* which carry from the intestine the absorbed fatty materials of food, unite to form a *thoracic duct,* which extends anteriorly and empties into the venous system near the heart.

The Respiratory System. At the anterior end of the *larynx* is a cartilaginous flap called the *epiglottis* (Fig. 215). The

lungs are larger and more extensible than in the birds and hang free in the thoracic cavity. Respiration is effected mainly by movements of the diaphragm and the ribs, thus altering the size of the thoracic cavity and causing air to enter and to leave the lungs.

The Excretory System. The *kidneys* (Fig. 215) are bean-shaped bodies in the dorsal part of the abdominal cavity. The *ureters* lead from them to the *urinary bladder*, whence the waste products are carried to the surface by the *urethra*.

The Skeletal System. The skeleton is, in general, built upon the plan with which we have become familiar in the study of the frog, the lizard, and the pigeon. The *cranium* (Fig. 215) is articulated to the vertebræ by two condyles, as in the amphibians. All the *vertebræ*, except those in the pelvic region, are free.

The Nervous and Muscular Systems. The nervous system is similar to that of the bird, but the *cerebrum* (Fig. 215) is considerably more differentiated. The *muscles*, especially those in the hind legs, form a complex system adapted to strong and rapid movement.

The Reproductive System. The organs of reproduction in the male consist of oval *spermaries* (Fig. 215) and a *penis*; in the female, of *ovaries* with their *oviducts*.

Development. The squirrel is viviparous. The ovum produced in the ovary passes into the oviduct, where it becomes fertilized. In that portion of the duct called the *uterus*, it develops into the young squirrel. The young is born in a condition resembling the adult, though the hair is not completely formed and the eyes are closed. In the Southern states the first of two or three litters appears early in March, and four young are usually produced at a birth. The nest is usually in a hollow tree in the colder portions of the squirrel's range, and exposed on the branches in the warmer regions. The female keeps the male away from the young

during their period of infancy and feeds them on milk, which is secreted by the *mammary glands* on her ventral surface.

Relation to Environment. When the young have been reared, the winter nest in a hollow tree is usually deserted for a structure of leaves and twigs built high among the branches of a tree. This outside nest is occupied (at least in the colder regions) throughout the summer.

The food of the squirrel in the spring consists largely of buds, especially of the maple and elm. In the summer, fungi and berries are added to the bill of fare, and in the fall nuts form a large part of the diet. The gray squirrel has been accused of varying its vegetable diet with such animal food as the young and the eggs of song birds, but it is probably not as frequent an offender as the red squirrel, whose bad habits in this respect are well known. The nuts of autumn are gathered and stored in secret places beneath stumps and in hollow trees, and many are separately buried in the ground. Some observers are inclined to think that their sense of smell guides them to the buried food, though it is doubtful if these individual hoards are always located again.

When winter comes on, gray squirrels are likely to be later in rising in the morning, preferring to come out in the warmest part of the day, and on some inclement days they may not venture forth at all. There is no evidence, however, that they truly hibernate.

Gray squirrels have been known to travel in bands from place to place. Of late years, either on account of their much diminished numbers or because of change in the food supply, we see little of the great migrations which formerly occurred. Many such visitations have been recorded. Pennsylvania was overrun with squirrels in 1749, and a bounty of threepence a head was offered for their destruction. It is estimated that about six hundred and forty

thousand squirrels were killed at that time. In their migrations bodies of water were crossed by swimming, though ordinarily squirrels are not lovers of water. The cause of the migrations is probably to be looked for in scarcity of food supply.

The general color of the gray squirrel's fur is protective, and the animal has the habit of flattening itself on the upper side of a horizontal branch, so that it is invisible from below. Of their enemies, the hawks probably give them most trouble. It is said that the red-tailed hawks hunt them in pairs, thus making futile their habit of dodging to the far side of a branch.

Spread over a large area from Maine to Minnesota and south as far as Florida, it is to be expected that the different individuals will vary considerably. In general, it is found that the colors increase in intensity southward and in regions of copious rainfall, while the legs, tail, and ears show a tendency to increase in length. In all parts of their range individuals are sometimes born in which the normal coloring matter of the hairs is replaced by black pigment, and others in which the pigment is lacking, leaving the fur white. The black individuals are examples of *melanism*; the white, of *albinism*. Both conditions are quite common among squirrels.

The calls of the gray squirrels to each other may often be heard in the woods, especially in the fall. The "barking," as it is termed, consists of a series of notes ending in a longer snarl. It expresses anger, alarm, or warning. Gray squirrels have sometimes been encouraged to make their homes in city parks, where they soon learn to accept and finally to be largely dependent on contributions of food from human visitors.

CHAPTER XXXVII

THE ALLIES OF THE SQUIRREL: MAMMALIA

They say,
The solid earth whereon we tread

In tracts of fluent heat began,
And grew to seeming-random forms,
The seeming prey of cyclic storms,
Till at the last arose the man.

TENNYSON, In Memoriam

Definition of Mammalia (Lat. *mamma,* "breast"). The squirrel serves to introduce the Mamma'lia, the highest class of the animal kingdom. Man himself belongs to this class. Therefore all facts of structure and of function mentioned in the preceding chapter have especial interest for us. All mammals are much alike in their anatomy and physiology.

Mammals are warm-blooded vertebrates covered with hair. Generally two pairs of appendages are present, the anterior of which are never absent in any member of the class. Mammals breathe by lungs. Teeth are almost invariably present. In the majority of cases the "milk teeth" of the young are shed and an entirely new set develops in the adult. Mammals bring forth their young alive and feed them on milk, except in the very few cases to be referred to under the Monotremata below.

The principal orders into which the class is divided are mentioned in the following pages.

The Duckbill and Allies. The duckbill (*Ornithorhyn'chus anati'nus,* Fig. 216) and two or three species of spiny anteater (*Echid'na*), mammals of the size of a rabbit and found only in Australia, Tasmania, and New Guinea, have many

special characteristics. The name "Monotrem'ata" is given to them in reference to the fact that these mammals possess but a single opening (cloaca) through which the contents of the intestine and the urinary and reproductive products pass outward, as in the case of amphibians, birds, and reptiles. Monotremes also stand alone among mammals in the fact

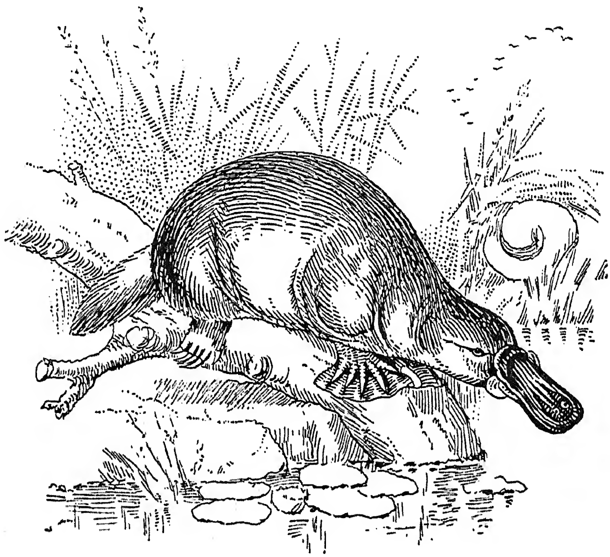


FIG. 216. Duckbill[1]

that they lay eggs inclosed in a white, flexible shell, much like the egg of a reptile. The duckbill gets its name from its peculiar duck-like beak, which is toothless when the animal is full grown, the teeth being shed after they have been used for a while. The male has a hollow spur on the heel, which is connected with a poison gland in the thigh. The duckbill is semiaquatic, and lives in burrows in the banks of ponds and streams. Its food consists of mollusks, small insects,

[1] From Lydekker's *Geographical History of Mammals*.

worms, and crustaceans. Spiny anteaters are inhabitants of elevated rocky districts and feed on ants. They are protected by a covering of spines intermixed with the hairs.

Kangaroos, Opossums, and Allies. The order Marsupia'lia (Lat. *marsupium,* "pouch") contains a large number of species, most of which are confined to Australia and the

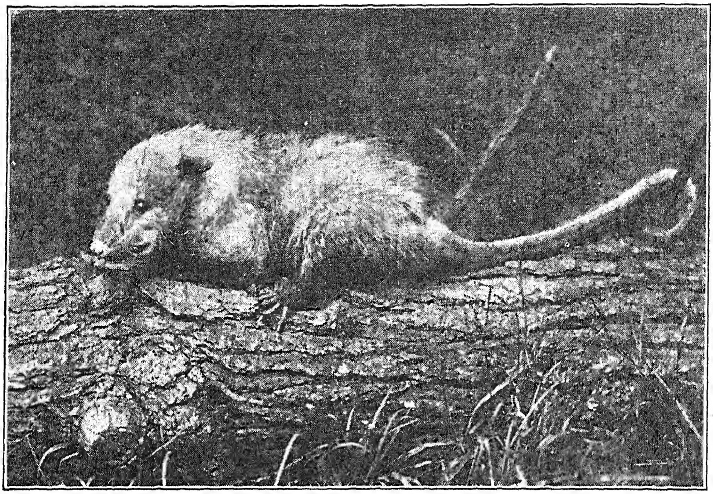


FIG. 217. Photograph of an opossum

surrounding islands. The mammals comprising it are of various external form, but the females of nearly all species have an abdominal fold of skin forming a pouch in which the almost helpless young are placed by the mother when born; they are then carried about with her until they are able to take care of themselves. The kangaroos vary from the size of a rabbit to that of a sheep. The hind legs are developed for jumping. The Virginian opossum (*Didel'phys virginia'na,* Fig. 217) of our Southern and Middle Atlantic states is the most northern member of the opossum group, many species of which are found in South and Central America. It has the

habit of feigning death when in danger of capture, hence the expression, "playing possum."

Fossils from the rocks of the latter part of the Age of Reptiles show that marsupials were widely distributed over the earth at that time. Then came the separation of the Australian continent from the land to the north, isolating the marsupial fauna from the larger and more diversified land areas. The Australian fauna evolved along various lines, producing herbivorous, insectivorous, and carnivorous forms which resemble in outward appearance the members of the higher orders of mammals, though they are in reality marsupial in structure. Over the rest of the world, with the exception of America, the marsupials were entirely destroyed and their places taken by more highly specialized types. Marsupials retained a foothold in South America owing to the absence of overpowering enemies, and on account of their adaptation to climatic and general environmental conditions. They afford an illustration of discontinuous distribution.

Sloths, Armadillos, and Allies. Both terrestrial and arboreal animals are included in the order Edenta'ta (Lat. *e*, "out"; *dens*, "tooth"). Edentates have incompletely developed teeth, or if the teeth are well developed, they are of simple structure; true incisors are never present. Many members of the order have a covering of scales formed from the hardening of the skin.

The armadillos (Fig. 218) are terrestrial American forms which are protected by the scaly covering just referred to. The tail and head are generally exposed, but the animals can roll themselves into a ball, thus offering a hard surface in every direction.

The sloths of South and Central America are nocturnal, arboreal animals; their natural attitude during the day is hanging from a branch back downward. The hair is gray, but in some species it offers a lodgment for a green alga, a

plant of low organization, which gives the hair a green tinge like that of the masses of vegetation of the tropical forest. Sloths rarely descend from the branches of trees. On the ground they are almost helpless.

Whales, Dolphins, Porpoises, and Allies. The whales, dolphins, and porpoises are true mammals, though so adapted to their aquatic life that they seem, on superficial

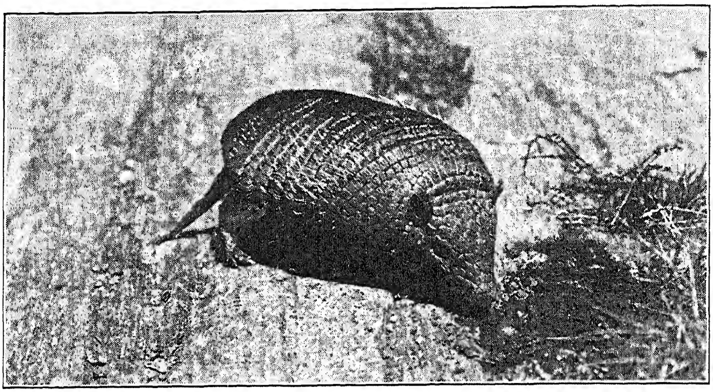


FIG. 218. Photograph of an armadillo

examination, to be fishes. The name of the order, Ceta′cea, is derived from the Latin *cetus*, "whale."

Flower and Lydekker, in their book on Mammals, thus review the principal peculiarities of the group:

The external fish-like form is perfectly suited for swimming through the water; the tail, however, is not placed vertically as in fishes, but horizontally, a position which accords better with the constant necessity for rising to the surface for the purpose of breathing. The hairy covering characteristic of all mammals, which, if present, might interfere with rapidity of movement through the water, is reduced to the merest rudiments, — a few short bristles about the chin or upper lip, — which are often present only in very young animals; and the function of keeping the body warm is performed by the "blubber." The fore limbs,

though functionally reduced to mere paddles, with no power of motion except at the shoulder-joint, have beneath their smooth and continuous covering all the bones, joints, and even most of the muscles, nerves, and arteries of the human arm and hand; the rudiments of hind legs, found buried deep in the interior of the animal, apparently subserve no useful purpose, but point an instructive lesson to those who are able to read it.

Cetaceans are found in all seas, and feed on fishes, crustaceans, and the smaller floating animal life of the ocean

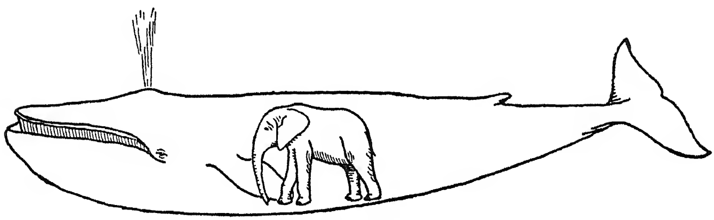


FIG. 219. Comparison of the size of an elephant with that of a whale[1]

generally. They vary from four to eighty feet in length, some of the whales being the largest of existing animals (Fig. 219). There is every reason to believe that the group is descended from land mammals. The whalebone whales are species without teeth, but with a development of baleen, or whalebone, in the upper jaw, which acts as a strainer. By means of the closely set, flexible strips of whalebone the small animals on which they feed are retained, while the water is forced out. Several species are found in the Atlantic and Pacific oceans. The sperm whale (*Physe'ter macroceph'alus*) has a square head, within which is a cavity containing oil which, on being refined, yields spermaceti.

Hoofed Mammals. The great assemblage of animals called Ungula'ta (Lat. *unguis*, "nail") includes the hippopota-

[1] From R. S. Lull's *Organic Evolution*. Used by permission of The MacMillan Company.

muses, pigs, camels, deer, the giraffes, antelopes, oxen, goats, sheep, rhinoceroses, horses, and elephants. All these mammals have the toes ending in either a blunt nail or a fully developed hoof, both of which structures are formed from the thickening of the skin of the toes. In ungulates like the cow and sheep there are two divisions in the hoof, and the animals really walk on the tip of the third and fourth digits, the others being much reduced in size. In the horse and its allies this reduction has gone much farther, so that the tip only of the third digit is used for support. The elephants have five toes, each incased in a short nail. The living species of elephants undoubtedly would have been removed to a separate order if fossil forms had not been discovered possessing characters intermediate between these mammals and other ungulates.

FIG. 220. Head of rhinoceros
American Museum of Natural History

Ungulates are adapted to a terrestrial life and feed almost entirely on vegetable food. Four kinds of teeth are present, — incisors, canines, premolars, and molars. The first kind and the last two kinds will be recognized from the study of the squirrel; the canines, so named because they are well-developed in the dog (Lat. *canis*, "dog"), fill the space between the incisors and premolars. The canines are often elongated to form tusks for defense or for obtaining food; the incisors serve to crop the herbage; the molars and premolars are flattened for grinding.

Horns for defense have been developed in many species of ungulates. They are of various sorts. The rhinoceroses (Fig. 220) have one or more median horns, which are composed of a thickened and hardened portion of the skin and hair, covering a short protuberance of the skull. In the giraffes there are one or two pairs of horns consisting of a layer of skin over bony processes of the skull. Neither in the rhinoceros nor the giraffe are the horns ever shed. In the North American pronghorn antelope (*Antiloca'pra america'na*) the horns are branched and consist of a hardened and thickened skin on a bony core. The thickened skin is shed periodically but the core is retained. The horns in true antelopes and in oxen, sheep, and goats, are of similar structure but are never shed. They are usually found in both sexes. In the deer family (Fig. 221) the horns, called antlers, consist of outgrowths of bone covered each year during the period of growth with a sensitive skin called "the velvet." When the annual growth is completed the supply of blood to the antlers ceases and the velvet peels off, leaving the bone bare. After a time the antlers separate from the skull and are shed. In most deer this takes place annually.

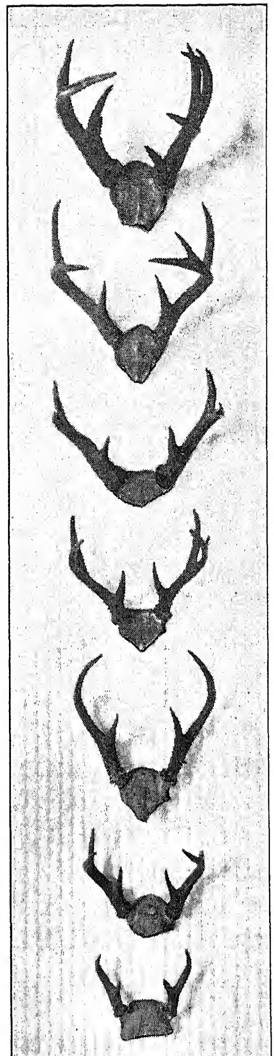


FIG. 221. Series of antlers

American Museum of Natural History

In some members of the family the antlers remain simple throughout life; in others they become much branched in successive annual growths (Fig. 221). It is interesting to note that, in a broad way, this was the order of development of antlers in geological time, the earliest deer of which we have any knowledge being without them. Horns and antlers are used in the battles of the males for the possession of the females, as well as for defense of themselves and their band. The presence of these organs is usually ascribed to the action of sexual selection.

A large number of the ungulates have learned the advantage of coöperation and live in herds, which possess an organized power of resistance far greater than any individual has. In many cases, especially among the deer, scent glands are developed on the head below the eyes, and as the sense of smell is extremely acute, notice of the presence of other members of the herd is given by the odor of the secretion from these glands. Often the tail and rump are conspicuously marked with white, showing plainly when the animal is in flight, and probably serving as a recognition or signaling mark.

The structural peculiarities already referred to form the basis for separating the ungulates into three divisions, — those with an even number of toes, as the cow; those with an odd number of toes (one or three), as the rhinoceros and horse; and the long-nosed forms (Proboscid′ea), including the elephants. Of the even-toed ungulates the families of camels (Camel′idæ), deer (Cer′vidæ) and antelopes, goats, sheep, and oxen (Bo′vidæ) have the stomach (Fig. 222) divided into a digestive and a nondigestive or storage region, forming a complex organ of several compartments. The food is taken into the first two of these divisions, the *reticulum*, or honeycomb bag, and the *rumen*, or paunch, where it remains till the animal has finished grazing and has

leisure for its digestion. The food is then raised to the mouth in a somewhat softened condition and is there ground between the molar teeth and moistened with saliva, after which it is again swallowed, this time into the *psalterium*, or manyplies, so called from the numerous folds in its lining membrane. The food slowly filters through the manyplies into the true digestive stomach, or *abomasum*. This very

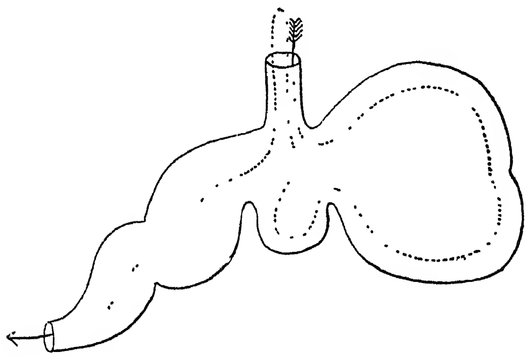


FIG. 222. Diagram of the stomach of a ruminant

Arrows and dotted lines show the course of food (After Wiedersheim)

characteristic habit of chewing the cud has suggested the name of ruminants (Lat. *rumen*, "throat") for these ungulates.

Most of the so-called wild horses are in reality horses which have escaped from domestic breeds. The tarpan of Central Asia is an exception. It seems to be truly wild, not feral. This horse closely resembles the pictures of horses made by man on walls of caverns and those carved on bone, which date back long before the beginnings of real history. The interesting story of the geological development of the horse is told farther on.

Of the Proboscidea the elephants alone require mention. There are two common present-day species, the Asiatic (*El'ephas in'dicus*) and the African elephant (*Elephas afri-*

ca'nus). The latter can be distinguished from the former by its very large ears. The Asiatic species has long been domesticated and many stories are told of its intelligence. The African species was used by the Romans in battle and circus games, but in modern times these animals have been hunted so persistently for their ivory that there is danger of their being exterminated. Steps are now being taken to prevent their complete destruction.

Gnawing Mammals. The Roden'tia (Lat. *rodere*, "gnaw") are the most numerous in point of species and are the most widely distributed of all the mammals. Here belong the hares, rabbits, guinea pigs, porcupines, mice, rats, beavers, woodchucks, prairie dogs, and squirrels. Rodents are distinguished by the absence of canine teeth and the presence of chisel-shaped incisors, which grow from persistent pulps (Fig. 214). They are mostly terrestrial animals, though a few, like the beaver, are modified for an aquatic existence, and others, like the squirrels, for life in the trees.

The hares are distinguished from all other rodents by the presence of a second pair of incisor teeth behind the first pair in the upper jaw. Well-known American species are the cottontail, or gray rabbit, of the East (*Sylvila'gus florida'nus*), the varying hare (*Le'pus america'nus*) of the North, and the northern jack rabbit (*Lepus campes'tris*) of the West. The cottontail is so named from the white tail, which is plainly shown in flight and probably serves as a signal or recognition mark. The varying hare is a larger and more northern species, which grows a white coat of fur in winter. The northern jack rabbit also changes to white in the northern part of its range; farther south the change is only partial or entirely wanting. The domestic rabbit is descended from the common rabbit of the Mediterranean basin (*Lepus cunic'ulus*).

The porcupine (*Erethi'zon dorsa'tus*) is a sluggish, stupid animal, which, having spines for protection, relies on them

to such an extent that it hunts its food in the daytime, — a habit which most rodents have had to give up (if they ever possessed it) on account of their lack of protection and means of defense against numerous enemies. The squirrels have solved the problem in another way by the development of extreme watchfulness. There is no truth in the oft-repeated statement that the porcupine can shoot its quills, the fact being that, as they are loosely attached, they are likely to come out on slight pressure.

So much has been written on the beaver and its works that its habit of felling trees for its dam or for food, its winter storage of branches or twigs beneath the ice, and the habits developed in connection with its communal life are pretty well known to everybody. In the communal life of the beaver, as among the bees and wasps, instinctive actions are performed with a high degree of perfection. The beaver also has capabilities of meeting new conditions, and it has been credited with a considerable degree of intelligence. It has been hunted so persistently for its fur and scent bags that it is now greatly reduced. In some localities where it is given protection, it is again becoming well established.

Flesh-Eating Mammals. The carnivorous mammals, Carniv′ora (Lat. *caro* (*carn-*), "flesh"; *vorare*, "devour"), are the flesh-eaters par excellence. The incisor teeth are small and sharp; the canines are generally long, strong, and conical, fitted for tearing; and the premolars and molars are raised into more or less sharp ridges. The toes are sheathed in claws, often fitted for grasping, and in one family, the cats, are capable of being retracted and thus kept sharp by being saved from constant friction. The group has divided along two main lines of development, one adapted to terrestrial, the other to aquatic, life. To the first belong the family of cats (Fe′lidæ), including the lion, tiger, leopard, lynx, jaguar, and puma; the hyenas (Hyæn′idæ); the dogs, wolves,

and foxes (Can′idæ); the bears (Ur′sidæ); and the raccoons (Procyon′idæ). To the second division belong the seals and walruses.

The jaguar is a South American cat resembling in general appearance the leopard of Africa, and, like it, an inhabitant of wooded regions, where it spends much of its time in trees. The irregular markings resemble in a general way the patterns of light and shade beneath the leaves of a forest. The markings are usually spoken of as an illustration of aggressive resemblance. The dun-colored lion and the gayly striped tiger are mentioned as similar examples, the one resembling the brown of desert places and the other the vertical shadows of reeds and grasses in tropical jungles. The origin of our domestic cat and dog, like that of some of our other domestic animals, is uncertain, but it is generally believed that the cat is descended from the Egyptian, or Caffre, cat (*Fe′lis caf′fra*), an African and Asiatic species domesticated by the Egyptians and held in veneration by them; the dog is variously thought to be the descendant of some wild species now extinct, or of one of several wolves or jackals, or a mixture of several species. The great length of time since the dog first became the companion of man, and the numerous races which have arisen, render the question extremely complicated.

Of our smaller wild carnivores none is more generally known and feared than the skunk (*Mephi′tis*), of which there are many species in the United States. Their powerful means of defense is a pair of glands secreting a strong-smelling fluid, which they are able to eject for a distance of several feet. Though they are destroyed by the farmer for robbing his henroosts, they are on the whole beneficial, as they feed largely on injurious insects. Those who have observed them most say that they make interesting and cleanly pets, even without the removal of the scent glands,

and that they are not prone to defend themselves except under great provocation. The presence of this means of defense has had its effect upon the skunk's character, so that if a person comes upon it in the daytime it is likely to make no special effort to escape, but goes about its business leisurely, secure in the confidence that it will not be molested. The Eastern species are black animals about the size of a cat, with prominent white stripes down the back and a white patch on the forehead. The white markings on the black ground are usually cited as an example of warning coloration. It has been asserted that it is advantageous to the skunk to be thus marked, for if it had a uniform black color, it might be mistaken in the uncertain light for other night prowlers and be pounced upon and killed by an enemy before it had an opportunity to use its peculiar method of defense.

Among the aquatic carnivorous forms the Alaskan fur seal (*Callota'ria alasca'nus*) has been the subject of international discussion on account of the value of its fur as an article of commerce. This is a truly migratory species of mammal, bringing up its young on the Pribilof, or Fur Seal, Islands (Fig. 223) in the summer, and going far to sea in the winter. The males do not reach their full size and strength till about the seventh year, and until that age the young males herd by themselves, being forbidden the general herd by the older males. The females mature in two years. Early in May the full-grown males appear at the islands, and the females a few weeks afterward. Each male immediately collects as many females as he can guard, and battles are frequent before the groups are made up. From twenty to one hundred females, or "cow" seals, are included in a single harem.

The government-owned seal herd in the Pribilof Islands is the world's chief supply of sealskin. This herd now totals

more than 723,000 animals. Only three-year-old "bachelor" males, who have not started a harem, are killed for the fur. In 1925 the Bureau of Fisheries supervised the taking of twenty thousand skins.

Insect-Eating Mammals. The insect-eating mammals, Insectiv′ora, are usually of small size. The teeth are sharp and numerous, and the molars have sharp points for crushing

FIG. 223. A colony of fur seals in Alaska
From United States Bureau of Fisheries

the bodies of insects. The eyes are often small and hidden in the fur, especially in the forms which, like the moles and shrews, burrow in the ground. The star-nosed mole (*Condylu′ra crista′ta*) is a common American species living in peat swamps and rich land near ponds and streams. They make great burrows, and the earth thrown up may sometimes make a pile a foot or more in diameter. The name is given from a fleshy filamentous appendage on the nostrils, which is probably used as an organ of touch. Some of the

shrews are the smallest mammals known. They generally live in burrows like the moles. They somewhat resemble mice, from which they can be distinguished by the different plan of the teeth.

Bats. The Chirop'tera (Gr. *cheir*, "hand"; *pteron*, "wing") are marked off from all other mammals by the possession of wings, which are formed of skin stretched over the bones of the arm, including also the legs and sometimes the tail.

FIG. 224. Photograph of a bat

So well adapted for aërial locomotion have the bats (Fig. 224) become that progress on the ground is almost impossible. The sense of touch is greatly developed not only on the muzzle but on the wings as well, so that the animals are able to avoid obstacles in their nocturnal flights. During the day bats hang themselves up by their legs in caves and in hollow trees to sleep. Some species feed on insects, others on fruit, and some, the vampire bats of Central and South America, feed on blood. The latter have the teeth peculiarly adapted to cutting the skin of animals. The esophagus is so narrow that no solid matter can pass down it.

Primates. The Prima'tes (Lat. *primus*, "first") include the monkeys, apes, and man. The teeth are generally adapted to a diet of both plant and animal food; the five toes and fingers are separate and are usually provided with

nails; the thumb is opposable to the other digits, and the eyes are directed forward.

The spider monkeys (*At'eles,* Fig. 225) of South and Central America are representative forms of the New World

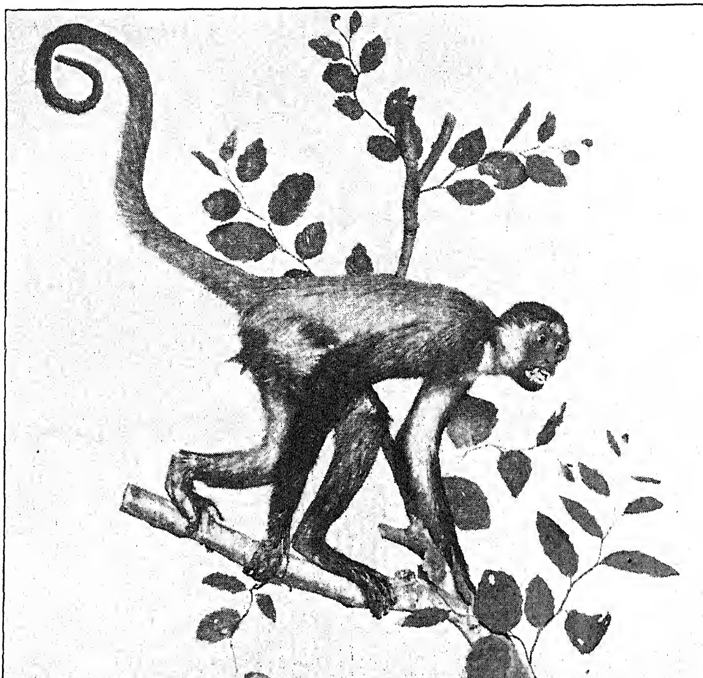


Fig. 225. Photograph of a spider monkey

American Museum of Natural History

monkeys. They have a long tail, which serves as an organ of prehension. The most man-like of the monkeys are the orang-utan (*Sim'ia sat'yrus*) of Borneo and Sumatra, and the gorilla (*Goril'la goril'la*) and chimpanzee (*Anthropopithe'cus troglody'tes*) of equatorial Africa. Of these the chimpanzee (Fig. 226) is the most gentle in disposition and

the most intelligent. All these monkeys lead a more or less arboreal life and build nests in trees, where the young are produced.

That man belongs zoologically in the same group with the monkeys is now universally admitted, for in the structural characters upon which classification largely depends, as Professor Huxley pointed out many years ago, he differs less from the apes, which resemble him most, than they do from other monkeys. The principal anatomical characters are the possession of a relatively larger brain case and less-developed canine teeth, the adaptation of the vertebral column to an erect posture, the greater length of the lower as compared with the upper extremities, and absence of the power to oppose the great toe to the other toes. The similarity between man and the apes does not mean that man has descended from the apes. In fact through various discoveries of fossil apes and fossil man we have considerable knowledge about what each was like in past ages. We likewise know that there was a time when neither apes nor man existed on the earth. Before either of these animals came into existence there were other animals which were neither ape nor man but the common ancestor of both. In view of these facts it is no more nearly true to say that man came from apes than to say that apes came from man. Neither came from the other.

Intelligence of Mammals. There are many who ascribe to the birds and to the mammals below man mental attributes, including a power of reasoning, differing from the attributes of man not in kind but in degree.

In the past few years there have been many students working on the problem of intelligence in the lower animals. In the earlier period of this study emphasis was placed upon the attempt to discover whether animals below man really have intelligence, or are simply machines reacting in a

mechanical manner to outside forces. Finally, after many hundreds of experiments and many conflicts in definition of terms, the students in animal behavior have come to the conclusion that man is not the only animal possessing an intellect. In the animals below man we find the beginnings of reason and the various emotions. Very recently much attention has been directed to the study of the intelligence of some of the higher apes, especially the chimpanzee and the orang-utan. In a book entitled *Almost Human*, Professor R. M. Yerkes of Yale University has reviewed a good many observations and interesting experiments on the higher apes. In one experiment a banana is placed above the reach of a chimpanzee. He piles boxes one on top of another until he can climb high enough to grasp it. Is it possible to explain such behavior as accidental, requiring no mental activity?

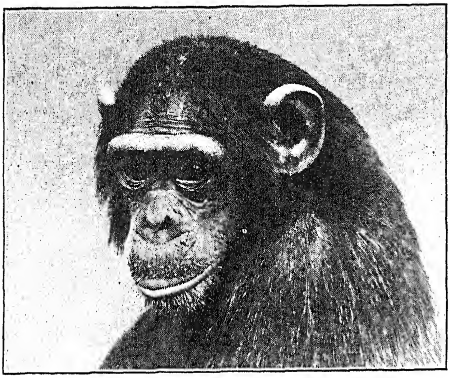


FIG. 226. Portrait of a young chimpanzee

Photograph by Elwin R. Sanborn, courtesy of the New York Zoological Society

Economic Importance of Mammals. The mammals come into more intimate relations with man than any other group of animals except the insects. From them he gets materials for dress, — wool, leather, and furs; food in the shape of butter, cheese, and meat of different kinds. They are his beasts of burden the world over, and they furnish a long line of miscellaneous products, such as horn, bone, ivory, perfumes, whalebone, oils, fats, and material for fertilizers. The following paragraphs tell of other relations.

Mammals in the War on Disease. Even a brief summary of the facts regarding the importance of mammals to man must include some mention of the rôle which mammals have played in the development of modern medicine. By far the greatest advance in our war on disease has been in the direction of the prevention of disease. Much that we now know about human ills has resulted from laboratory studies in which rabbits, guinea pigs, and other laboratory animals have been used in experiments. Further than this, many mammals have aided directly in curing and in preventing human disease by producing *serum* and *antitoxin.*

In the blood of cows the germs of cowpox are produced. These are very nearly like the germs of the dreaded smallpox. When cowpox germs are introduced into the human body by *vaccination* they cause the blood to become *immune* to the more dreaded and highly fatal smallpox.

When the germs which cause diphtheria are injected into a horse, the blood of the horse produces substances called antitoxins. These neutralize the effects of the poisons, or *toxins,* formed by the germs. The blood of the horse produces more antitoxin than is needed to kill the germs that were introduced into it. When antitoxin from the blood of the horse is injected into a diphtheria patient, the disease is checked. Furthermore, it has been discovered that diphtheria may be avoided altogether. When a mixture of the antitoxin and a small amount of the toxin of diphtheria are injected into the blood of a child, the antitoxin prevents the toxin from injuring the child, but at the same time the toxin causes the blood to produce its own antitoxin. When this *toxin-antitoxin* treatment is given, the child becomes immune to diphtheria.

In some diseases the dead germs introduced into the human body produce immunity to the disease. The germs of typhoid are grown, or "cultured," in the laboratory. After

these germs have been killed, a fluid containing the dead bacteria is injected into the body of a man. The presence of the dead germs in this instance causes the blood to manufacture antitoxins for this particular germ. As a consequence of this treatment the individual becomes immune to typhoid.

Rabies, scarlet fever, and lockjaw are others of the list of dreaded diseases from which immunity may be secured. Experiments on animals have thus relieved man from some of his most dangerous enemies.

Fur-Farming. As the country has become more densely populated the natural supply of furs taken in the wilds by trappers has steadily decreased. In recent years an entirely new industry has been developed. Various kinds of wild and domesticated animals are being bred and raised in captivity for furs. Fox-farming has become an important industry in many localities. Skunks, minks, and rabbits, as well as many other animals, are being raised for their skins.

Mammals as Pests. Next to the insects the mammals include some of man's worst enemies. In the frontier days of our own country wolves, bears, foxes, and coyotes caused great damage to flocks and herds of domestic animals. Skunks, minks, and weasels prey upon birds, including domestic fowls. Rabbits and other rodents destroy trees, shrubs, and vegetable gardens. Coyotes, prairie dogs, and woodchucks by their burrows damage fields and pasture lands and frequently are the cause of injury to horses and cattle which step into their burrows. Rats have become so destructive that it is estimated that every rat eats at least two dollars' worth of food a year. In addition the rats are a necessary link in the chain for spreading one of the most dreaded of human diseases, — bubonic plague.

Wild-Life Sanctuaries. In addition to the bird protection mentioned earlier, our national parks and forests give pro-

tection to many of our game animals. In separate reservations, as well as in parks and forests, many of our big-game animals are being given a new lease of life and kept from extermination. Bisons or buffaloes, elk, antelopes, and deer have been given special attention, and reservations have been set apart for their protection. When natural conditions demand it, the herds are supplied with food and thus kept from starving in severe winters.

Mammals of Past Ages. With the upheaval of the Rocky Mountain system at the close of Mesozoic time the North American continent assumed practically its present outline, with the exception of a strip along the southeastern coast, which was still beneath the level of the ocean. In connection with this disturbance of level and the accompanying climatic changes the great reptiles so characteristic of the period became extinct and left the field clear for the development of the mammals. The succeeding period is therefore called the *Age of Mammals*. As we have already seen, representatives of each group of animals have appeared before the age which bears its name, so the first mammals of which we have any knowledge are to be credited to the Age of Reptiles. They were nearly all of small size and allied to the marsupials and monotremes of today, — groups which we have noticed as being the lowest of the class.

During the Age of Mammals there were extensive areas of fresh-water lakes in western North America. It is from these deposits that much of our information regarding the early mammals of America has been obtained. The American Museum of Natural History in New York City has on exhibition a large series of fossils from this region. Many of the specimens discovered are of generalized structure. They possess the characteristics of several different groups of today, without much modification to a particular kind of life or food. It is among such animals that we must look for the

ancestors of the species of today, for no species of mammal which was in existence in the Age of Mammals has lasted through to the present time.

Of few other animals have we so complete and satisfactory a geological record as of the horse. From fossil remains found in the western part of the United States we

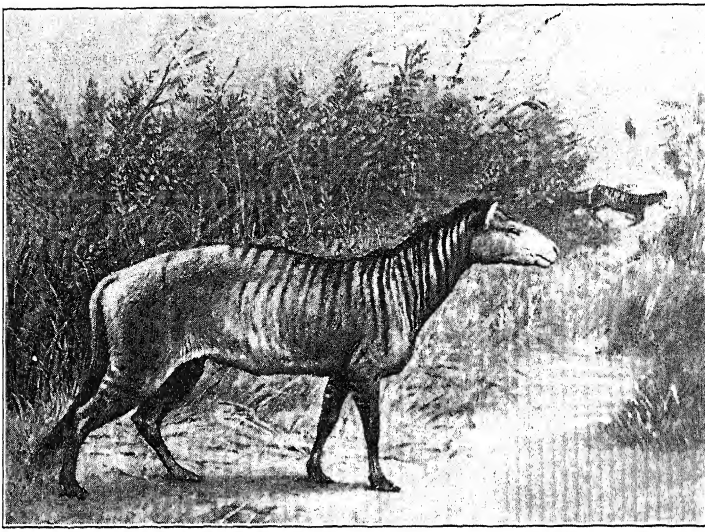


FIG. 227. Reconstruction of an early fossil horse (*Eohippus*)
American Museum of Natural History

are able to trace its evolution from an ancestor (*Eohip'pus*, Fig. 227) a little larger than a cat, with four toes on the front feet and three on the hind feet. The figure of *Eohippus* is photographed from a water color by Mr. Charles R. Knight, based on skeletal material at the American Museum of Natural History. The markings are drawn as they are supposed to have existed on the animal. There is reason to believe that the undiscovered ancestors of this early form had five toes on each foot. The transition to the

horse of today has been accomplished by a gradual increase of size, a reduction in the number of toes, and a reduction in number and an increase of complexity in the teeth. The main steps in the evolution of the horse are shown in Fig. 228. The changes in the limbs fit the animal for rapid locomotion over level, grassy ground. The teeth become more complex and more efficient grinding organs. In the latter part of the Age of Mammals, North America was broadly connected with Asia, and the horse is known to have inhabited plains of all the continents excepting Australia. After the horse had reached practically its present state of development (in the early part of the next succeeding period, the Age of Man) it seems to have disappeared entirely from America, owing to causes not thoroughly understood, though generally ascribed to the oncoming cold of the Glacial Epoch. The horse persisted, however, in Europe and was one of the animals which primitive man domesticated. The various uses to which the horse could be put were gradually learned by man, for Professor Osborn of the American Museum of Natural History says there is "abundant proof that man first hunted and ate, then drove, and finally rode the animal." It was reintroduced into America by the Spaniards at the time of their conquest, and soon ran wild.

The carnivores were early represented by generalized types, and later by dogs and saber-toothed cats. The latter get their name from their lengthened canine teeth. Insectivorous mammals, rodents, bats, ungulates of many kinds, and even the Primates, also occurred, and in the waters of the oceans were found cetaceans of different species.

The Age of Mammals began in North America with a warm climate, as in the case of previous periods, but toward its close frigid conditions began to prevail, probably due to the gradual elevation of the continental land-mass. The oncoming cold produced in the northern part of both America

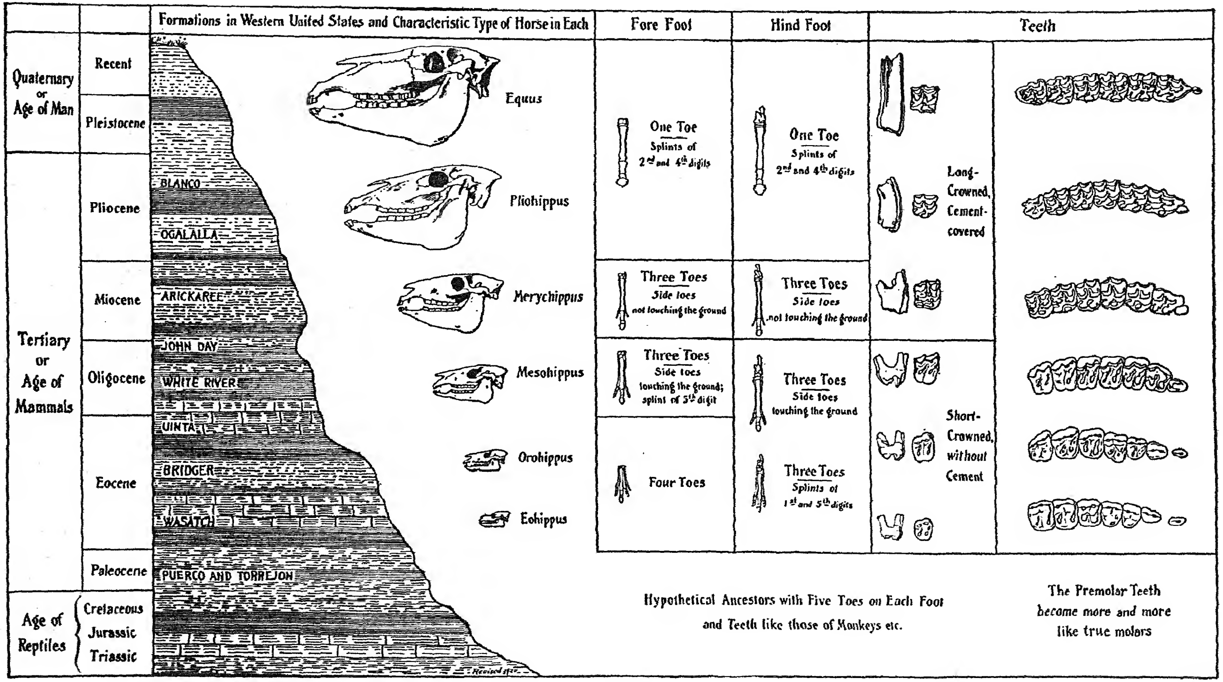


FIG. 228. Table showing the evolution of the horse
American Museum of Natural History

and the Eurasian land-mass conditions so severe that to the period the name *Glacial Epoch* is given. During its continuance all of North America north of a line drawn from New York through Pennsylvania, Indiana, Missouri, South Dakota, Montana, and Oregon was covered at different times with a layer of ice, which in certain regions grew to be a mile thick over the land, destroying all life or forcing it to migrate southward to escape the rigors of the climate. As there were several invasions and retreats of the ice, there may be said to have been several glacial epochs, separated by long periods of warmer weather, when the animal and plant life could slowly work its way back on the edge of the retreating glaciers. There is a peculiar interest to this period, inasmuch as it introduces the last of the great geological eras, the *Quaternary Period*, or the *Age of Man*.

A conspicuous feature of the mammalian life of the Age of Man was the great size of many of the species. After the opening glacial epoch the climate became mild again, and this seems to have forced the development of abundant vegetation and great mammalian forms. One of the largest and most widely distributed species was the mammoth (*El'ephas primige'nius*, Fig. 229), a proboscidean larger than the elephant of today and covered with a thick coat of hair, an adaptation to cold temperate regions. Its remains have been found frozen in the ice of Siberia, the hair and flesh perfectly preserved. Early man knew of this great mammal, for a drawing of the creature is in existence, made on a piece of its own tusk (Fig. 230). The mastodons were somewhat similar to the mammoths, but fitted on the whole for a warmer climate. There are over thirty species of mastodons known, of nearly world-wide distribution. They have become extinct within so short a time, geologically speaking, that traditions of their existence as living animals occur among men.

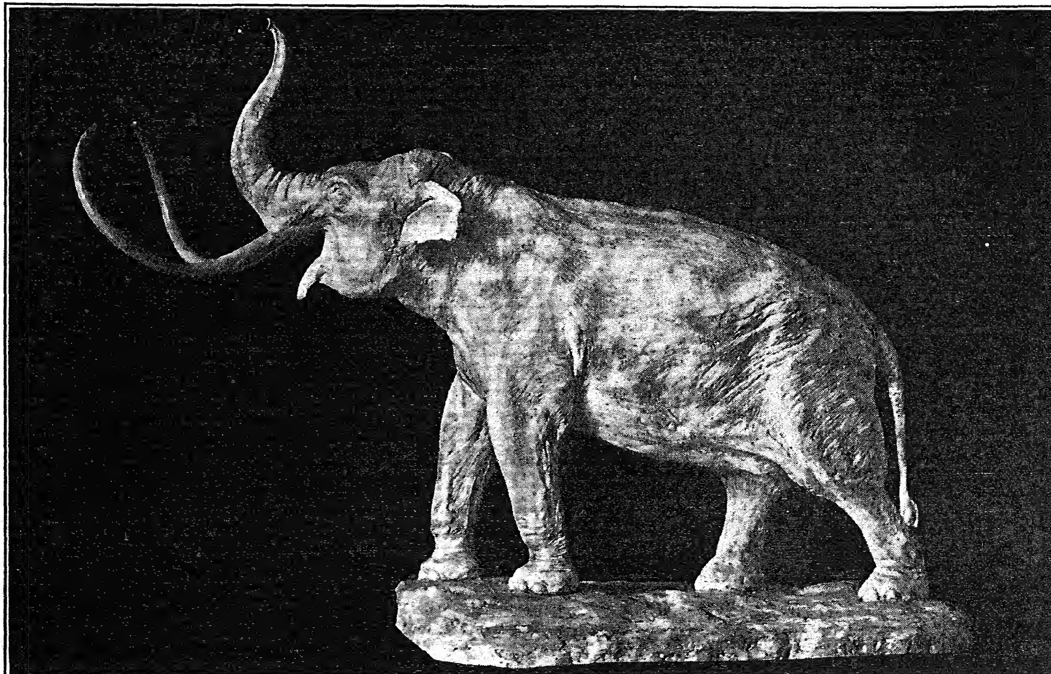


FIG. 229. Photograph of a model of a mammoth
American Museum of Natural History

The remains of giant edentates have been found in South America. Recent discoveries seem to show that some of them were living within the period of man on that continent, for some of the tribes of South American Indians have traditions respecting these monsters. In Europe and Asia there were lions, hyenas, bears, rhinoceroses, and gigantic ungulates. In Australia, as will be expected from what has been said of the distribution of the group, there were marsupials of various species, but none of the higher mammals.

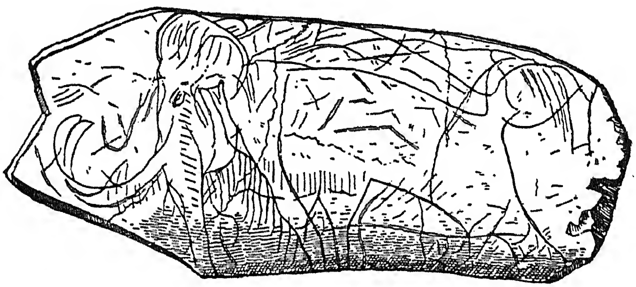


FIG. 230. Drawing of a mammoth made by prehistoric man on mammoth tusk[1]

But the great interest of the Age of Man centers about man himself. If it is not yet possible to prove to the satisfaction of everyone the existence of man in the Glacial Epoch in North America, it is certain that he was in existence in Europe at that time. It would be interesting to know, if possible, how far distant we should place this period, and where man first appeared on the earth, but to neither of these questions can any satisfactory answer be given. Regarding the time, estimates have been made in various ways, reaching conclusions which vary greatly. A conservative estimate is that the Glacial Epoch began two million four hundred thousand years ago and ended eighty

[1] From Lucas's *Animals of the Past.*

thousand years ago. Regarding the place of man's origin, some have believed that his earliest home was Africa, because the great apes, which most resemble him, live there today. Others have maintained that it was somewhere in equatorial regions, where the vegetation is abundant and the climate quite similar throughout the year; others claim that it was on some of the high plains of the temperate zone, like those of Persia and Tibet.

Primitive man was a savage, living in caves. His principal means of defense, in addition to those with which nature had provided him, were a stone picked from the ground or a bough broken from a tree. At an early stage in his development he learned the use of fire, made clothing of the skins of wild beasts to keep himself warm, and fashioned rude implements out of bone, shell, horn, wood, and stone. In those places where such easily worked metals as copper and zinc were accessible man early learned their use and made from them implements of bronze, a compound of the two metals. From a hunting existence arose the nomadic or wandering life, with property in the shape of herds of domesticated or semidomesticated animals, and the more fixed agricultural condition in which the main dependence for food was on the products of the field. We see people today in each of these conditions of existence. Along with the advance in the mode of life has gone a mental and moral evolution as man's conquest of nature has been pushed through wider and wider fields.

CHAPTER XXXVIII

THE HISTORICAL DEVELOPMENT OF ZOOLOGY

The history of the transformation of opinion in reference to living organisms is an interesting part of the story of intellectual development.

W. A. Locy, Biology and its Makers

The Science of Zoology and its Divisions. This is a textbook of zoology because it attempts to give, in orderly fashion, facts about animals. But not all of these facts are obtained from one kind of study. When in the foregoing chapters we were examining the general form of animals we were dealing with *morphology*. When the study of form went into the form and arrangements of the individual organs or parts we were taking up that branch of morphology which is called *anatomy*. When parts or organs of two different animals were compared or contrasted we were delving into a field of zoology called *comparative anatomy*. But structure is of live interest only when we come to see what the individual organ or part does. This field of zoology treating of function is called *physiology*. Before we were able to talk about either the form or function of the parts we found it necessary to call the animal by some name. This division of zoology is called *systematic zoology*, or *taxonomy*. When we discussed the relations of the various animals to their environment we were attacking one phase of the field of *ecology*. When we have discussed the animal life of the past we have been delving into the field of *paleontology*.

From the foregoing it becomes apparent that zoology is not a simple aggregate of facts, but these facts may be grouped into a great number of different subdivisions or sub-

sciences. Many of these in turn are capable of still further division. We shall turn now to the history of zoology. After seeing the many avenues along which animal studies may be approached we are in a position to appreciate the fact that the history of such a diversified science cannot be simple.

The Background of Zoological History. We have proof that man has known something about animals since before the dawn of history. There are caves in southern France where man lived long before the period of which we have any consecutive record, or history. On the walls of these caves are pictures of deer and of horses. These pictured animals are entirely different from any of the animals now living, but like the ones of a past geological period. Doubtless these were the animals which primitive man hunted. The drawings in the caves and the carvings on bone from these same ancient homes of prehistoric man show us that he had a considerable knowledge of animals. But there was no zoology at that early period, for in our definition we must include the statement that zoology is the *science* of animals. The knowledge which the ancient races of mankind had concerning animals merely furnished the foundation on which zoology could be built in later generations. For a science consists not alone of facts but requires that these facts shall be arranged in such manner as to show how they are related to one another.

No one knows when these facts with which primitive man must have been familiar became knit together into a science of zoology. The earliest person of whom we definitely know as a writer on animals is the Greek philosopher Aristotle (Fig. 231), who lived in the fourth century B.C.

Zoology in the Middle Ages. In spite of its venerable beginnings in the period of Greek culture and learning, zoology never prospered as a separate science and profession until modern times. Throughout the important epochs of

Greek and Roman history and on down through the Middle Ages zoology and most of the other sciences developed as mere appendages of the medical profession.

Discovery of the Microscope. Interesting as they are, the discoveries as late as those of the sixteenth and seventeenth centuries merely paved the way for the real development of the various branches of zoology. About the opening of the seventeenth century the microscope was invented. A Dutch spectacle-maker, named Zacharias Jensen, is usually credited with its invention. The development of this instrument opened an entirely new field of entrancing interest. Then for the first time man became aware of the teeming world of minute life. So also was the way opened for an understanding two centuries later of the structure of the animal body.

FIG. 231. Aristotle

Beginnings of Classification. All through the centuries there had been no uniformity in the names used for the various animals. As knowledge spread and interest in living things grew this lack of uniformity in names became more and more apparent. To the Swedish scientist Carl Linnæus (1707–1778) we are indebted for a system of exact naming. He is generally called the father of systematic zoology (Fig. 232). He devised a system called binomial nomenclature wherein each kind of animal is known by a name composed of two words,

— the name of a larger group, or genus, plus a name for the species. His system of names (first published in 1735 and finally perfected in 1758) is recognized as the basis of all modern classification of both plants and animals.

Comparative Anatomy and Paleontology. In the early part of the nineteenth century a French naturalist, Georges Cuvier (1769–1832), greatly influenced the development of zoology. In his studies of fossils he recognized them as the remains of animals of past times and related to the animals of today. Thus he founded the science of paleontology. Furthermore he realized the importance of anatomical structure in classification, and is recognized as the father of comparative anatomy.

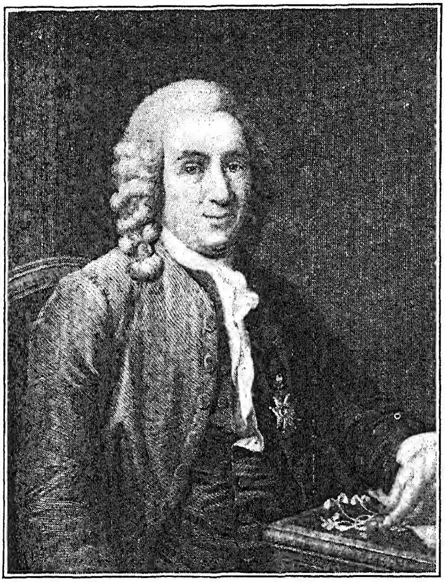


FIG. 232. Linnæus

The Cell and Protoplasm. In the two hundred years following the invention of the microscope many observations on the minute structure of living things were published. Most of these were scattering observations. In 1838 a botanist named Schleiden, and one year later a zoologist named Schwann, became convinced that the tiny units which various people had observed in both plant and animal tissue are the fundamental units of which all living matter is composed. Thus arose one of the most important generalizations in biology

up to that time. Later work by the German scientist Max Schultze showed that not only are plants and animals composed of similar units (the cells), but the actual living material, or protoplasm, is identical in plants and in animals.

The Origin of Species. One of the outstanding contributions of the nineteenth century to scientific thought was the serious study of evolution. As a philosophical principle evolution had been discussed since the days of Aristotle. No one person has had greater effect in stimulating thought and research in natural science than Charles Darwin (Fig. 233), whose works have been discussed in another chapter.

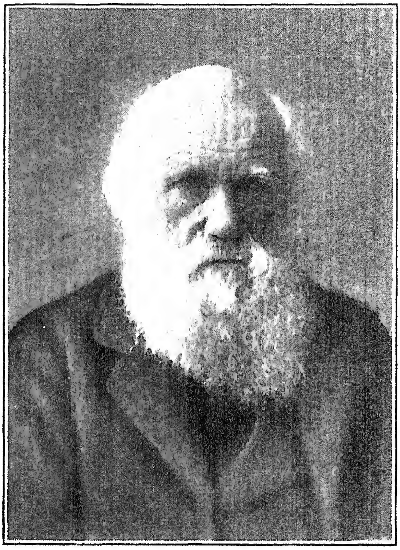


FIG. 233. Charles Darwin

He brought together huge volumes of facts from nature in support of his arguments. Such an array of facts was never before assembled. This statement may be more readily appreciated when we understand the methods used in science from its beginnings on down through the Middle Ages. In all branches of learning, as well as in the sciences, the proof of a statement or the validity of an expression rested upon the statements of older writers. The words of an authority passed for fact and were unquestioned. Science owes a debt to the philosopher Roger Bacon for altering this manner of getting at truth. Through his teaching in the thirteenth century,—that we arrive at facts only by observation of

nature and by experiment,—he brought about a complete change of attitude toward the nature of truth. Authority, except when it depends upon facts obtainable by any other searcher after truth, has no place in science. Our whole development of laboratory science and research resulted from the application of Bacon's principles of philosophy.

Spontaneous Generation of Life. The origin of life has been a problem on which man has speculated since his earliest history. Until fairly recently it was commonly believed that living animals are being continuously formed out of lifeless matter. By simple observation men witnessed that cheese placed in a cupboard seemed to turn into mice. Further, when meat was allowed to stand in the open, it soon gave rise to blowflies. Such observations were common enough and unchallenged by most persons. At that time no one understood how mice develop or how flies come only from eggs. In fact, the idea that lifeless matter could turn into living beings was not finally disproved until the time of Pasteur. About 1860 Pasteur performed experiments which proved that even the simplest organisms are developed only from other living beings of their own kind.

Zoology in America. Various agencies have contributed to the advance of zoology in America. One of the most outstanding of these has been the support accorded to zoological research through federal and state funds. Our federal government from an early date has recognized the service of science to humanity. Through its Bureaus of Entomology, Fisheries, Animal Industry, and Biological Survey many economic problems have been solved. These bureaus have not confined their attention to the control of destructive or harmful animals. A program of researches in pure science has been carried out by all these bureaus in addition to their programs of economic work. Frequently the re-

searches on structure or habits or life history of an animal have furnished information of value in controlling animal pests, and also in protecting and propagating desirable animals or those of direct value to man. The United States Public Health Service has rendered immeasurable services to zoology in investigating the relations of parasites to the health of the nation.

In similar manner many of the states support, from taxes, laboratories which return to the people many times the amounts invested in protection of human lives and in bettering the economic conditions of many industries. The office of state entomologist, the numerous natural-history surveys, departments of health, water surveys, and other organizations supported by many states not only yield a return in valuable discoveries in economic zoology but have also been large factors in the advancement of pure science.

Societies. Public interest in animals has been stimulated in many ways, of which societies and museums are prominent examples. The Audubon societies were named in honor of our pioneer student and bird artist, J. J. Audubon. These societies scattered throughout the country and numerous other nature-study organizations are responsible in large measure for much of our legislation designed to protect birds. More recently sportsmen and all others interested in our native wild life have formed various societies and organizations, of which the Izaak Walton League is typical. Through the efforts of such groups, popular sentiment for conservation is being fostered.

Natural History Museums. Museums have played no small part in the advancement of science. Most of them render a service in educating the public in the wonders of nature, and some become centers for research and study. The National Museum, supported by our federal government, and private institutions such as the American Museum

of Natural History in New York and the Museum of Comparative Zoology at Harvard are examples of these institutions. They perform the double service of educating the public and at the same time, through expeditions and a corps of scientific workers, serve as research centers.

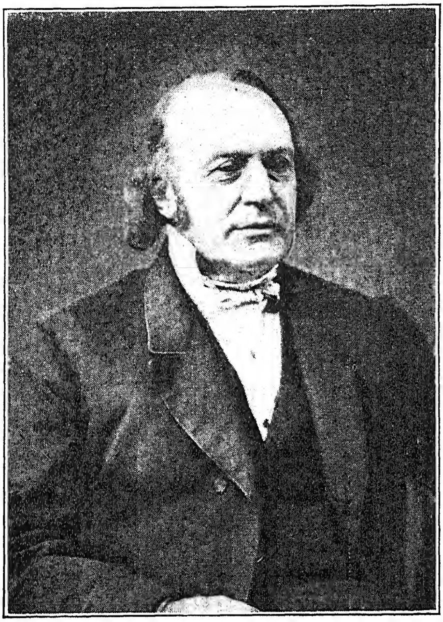


FIG. 234. Louis Agassiz

Teaching of Zoology in America. Any discussion of the teaching of zoology in this country always starts with the name of Louis Agassiz (1807–1873). A Swiss by birth, Agassiz (Fig. 234) came to this country when thirty-nine years of age. He was the founder of one of the greatest research institutions in the United States, the Museum of Comparative Zoology at Harvard. His summer laboratory at Penikese in 1873 was the forerunner of the marine laboratories. His slogan, "Study nature, not books," was largely responsible for the introduction in colleges of laboratory work in the sciences in place of textbook work alone. Since his time there have been many notable teachers of zoology in this country. Professor E. L. Mark of Harvard and Professor E. B. Wilson of Columbia might be mentioned as two who have played an unusual part in the training of teachers of zoology since Agassiz's time.

Practically every educational institution of any size and importance has made contributions to the advancement of zoology through its teachers and its students. In addition to these, many privately controlled and endowed laboratories have furnished the facilities for some of the fundamental contributions to zoology. The International Health Board has been very active in public health work both here and abroad. Much of what we know of human heredity has come from a laboratory at Cold Spring Harbor, New York, under the direction of Dr. C. B. Davenport. Marine laboratories where teachers and students may spend summers in study and research have been great factors in zoological progress. The pioneer laboratory at Woods Hole, Massachusetts, and several on the Pacific coast deserve mention.

In the foregoing paragraphs some of the many agencies for the advancement of the zoological sciences in this country have been passed in hasty review. These serve only as examples to show what diversity of interest and what variety of means have been enlisted in directing the growth of zoology in America. A complete list of the factors would require a large volume.

Science and Human Welfare. We live in an age which is commonly referred to as the Age of Science. Man has learned how to make use of and to control the forces of nature. No other beings have ever been able to make nature serve them in such manner. Most of the things which we have come to consider as conveniences or even necessities in our everyday life were unknown to our forefathers of a few generations ago. In most of the countries of the earth we find evidence that our civilization and our culture have extended back only a few thousands of years. Before that period most of our ancestors were what we today should call savages. All of us are aware that in America our modern civilization dates only from the seven-

teenth century. There are evidences that a rather high type of civilization flourished on this continent at an early period, but when the white settlers first arrived they found the Indians in a stage of development which is commonly called the Stone Age. This means that they formed stones into spearheads and arrowheads by chipping off pieces until the desired shape was attained. Weapons and most of the implements which they used were formed in this way. In some instances they had discovered how to use metal for making implements and decorations, but stone was the common material for all such purposes.

In Europe and Asia modern civilization was established long before it was in America. Yet even in these countries many remains of primitive man are still found. In the caves where men dwelt before they began to build shelters of their own many stone implements similar to those found in America have been discovered. Objects of the same sort found in the gravel deposits along streams give evidence that these early implements date from a time during or just following the geological period known as the Ice Age. These oldest signs of man's occupation of the earth are thought to date back several hundred thousand years.

It is only a few hundred years since superstition and magic played the greatest rôle in human thinking. Even as recently as two or three generations ago the causes of disease were attributed to evil spirits, as they still are by uncivilized tribes at the present day. The unknown to these people was shrouded in mystery. No attempt was made to understand what was not known. Though there are many things of which we today are still ignorant, we do not look upon many of these as unknowable. Much of this change in our attitude is due to the influence of science upon our thinking. Our highly trained physician with his laboratory for discovering the cause of disease has replaced

the witch doctor with his charms to conquer the evil spirits. Swampy regions where the "bad air" caused yellow fever and malaria in the days of our grandfathers have become healthful dwelling places since man through science has learned that mosquitoes, not the air, are responsible for the malaria and yellow fever. The United States succeeded in building the Panama Canal after other nations had been forced to admit defeat in the attempt, not so much because of superior engineering skill but as a result of knowledge of the manner in which certain diseases are spread. The diseases which killed off the workmen in the earlier attempts were controlled by the American engineers through a scientific knowledge of their causes which was not available before.

Through the information which the sciences have furnished us we now look upon the entire universe as governed by definite laws. Ignorance and superstition fall before the attack of knowledge. In the advance of our learning and of science each generation witnesses the discovery of new laws and principles governing nature. Many of these new laws and principles have application for living things as well as for lifeless material. Through these discoveries man has learned how to make the forces of nature serve him. In this discussion it is not worth while to go into the details of how man discovered that the waterfall might be harnessed and made to turn his machinery or to produce electricity. In this mechanical age we frequently forget that only a few thousand years ago there were no machines of any kind. All work that was then performed for man was done by his own hands or by his domestic animals.

Tremendous progress has been made in the past two or three generations toward applying the discoveries of science to the enriching and conserving of human life. So much has been accomplished in this direction that we may rightly raise

the question if there is a limit beyond which man may not go. Rapid transportation and ready communication are only samples of the commonplace experiences of today which we owe to the development of the physical sciences. Control and prevention of disease and improvement of living conditions are among the things for which advancement of the biological sciences is responsible.

There is one direction in which the limit of application of the discoveries of science is not even in sight, — that of race improvement. It is impossible to imagine what the future holds in store for the human race if man is able to make full use of all the knowledge contributed by science.

INDEX